



Is integrating acupuncture into the management of attention-deficit/hyperactivity disorder among children and adolescents now opportune and evidence-based? A systematic review with meta-analysis and trial sequential analysis

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ARTICLE INFO

Key words:

ADHD
Complementary and Alternative Medicine
Traditional Chinese Medicine
Traditional Medicine
Atomoxetine
Guanfacine
Conduct Problems
Learning Difficulties

ABSTRACT

Background and aim: The use of acupuncture is becoming increasingly popular in the management of attention-deficit/hyperactivity disorder (ADHD). This systematic review consolidates evidence on acupuncture's efficacy and safety for treating ADHD in children and adolescents.

Methods: Controlled clinical trials assessing acupuncture against waitlist-control, placebo or active controls, or as an adjunct treatment were systematically searched across seven databases from inception to November 2024. Cochrane criteria were adhered to.

Results: We reviewed 25 studies with 1758 participants. None compared acupuncture to placebo or behavioral therapy. Subdomain analysis of the Conners' Parent Rating Scale indicated that acupuncture and Methylphenidate had comparable effects on *Conduct Problems* [$SMD = 0.03$, 95 % CI (-0.93, 0.99), $p = 0.95$] and *Learning Problems* [$SMD = 0.29$, 95 % CI (-0.38, 0.97), $p = 0.39$], but acupuncture was more effective in controlling *Impulsive/Hyperactive* symptoms [$SMD = -1.71$, 95 % CI (-2.08, -1.35), $p < 0.01$]. Insufficient sample size prevented confirmation of potential false positives. Acupuncture was safer and reduced Methylphenidate-related side-effects, including appetite loss, sleep disturbances, dry mouth, abdominal pain, and constipation. Acupuncture combined with behavioral therapy outperformed behavioral therapy alone in improving *Psychosomatic* symptoms [$SMD = -0.88$, 95 % CI (-1.54, -0.23), $p < 0.01$]. In the Integrated Visual and Auditory Continuous Performance Test, ADHD patients receiving acupuncture alongside conventional care performed better than those receiving conventional care alone. Nevertheless, the methodological quality of the included trials was very low to low, with significant bias risk, and 88 % lacked follow-up.

Conclusions: Acupuncture may offer an alternative for children and adolescents with ADHD who are intolerant to medication (primarily Methylphenidate). When combined with medication or behavioral therapy, it appeared

Abbreviations: AAQ, Auditory Attention Quotient; AEs, Adverse Effects; ADHD, Attention-Deficit/Hyperactivity Disorder; AMSTAR-2, Assessment of Multiple Systematic Reviews 2; CAM, Complementary and Alternative Medicine; CHI, Conners' Hyperactivity Index; CPRS, Conners' Parent Rating Scale; CTRS, Conners Teacher Rating Scale; FSAQ, Full Scale Attention Quotient; FSRQ, Full Scale Response Control Quotient; ITT, Intention-To-Treat; IVA/CPT, Integrated Visual and Auditory Continuous Performance Test; MD, Mean Difference; NRCTs, Non-Randomized Controlled Clinical Trials; RCTs, Randomized Controlled Trials; RoB, Risk of Bias; ROB 2.0 Tool, Revised Cochrane Risk of Bias Tool for Randomized Trials; ROBINS-I Tool, Cochrane Risk of Bias in Non-Randomized Studies-of Interventions; RIS, Required Information Size; SNAP-IV, Swanson, Nolan, and Pelham Rating Scale; SR/MAs, Systematic Reviews and/or Meta-Analyses; SMD, Standardized Mean Difference; TCM, Traditional Chinese Medicine; TSA, Trial Sequential Analysis; TNA, Traditional Needle Acupuncture; VAQ, Visual Attention Quotient.

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<https://doi.org/10.1016/j.ctim.2025.103163>

Received 5 January 2025; Received in revised form 20 February 2025; Accepted 10 March 2025

Available online 12 March 2025

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more effective in ameliorating hyperactivity/impulsivity, inattention and conduct problems than standard treatments alone. It is also safe and well-tolerated. However, the supporting evidence is of low quality, and well-designed randomized controlled trials are needed. Thus, it is premature to recommend acupuncture as an alternative or adjunctive therapy for ADHD management.

1. Background and aim

Attention-deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental condition that typically manifests in childhood. It is marked by persistent, developmentally inappropriate patterns of inattention, hyperactivity, and impulsivity, leading to functional impairments across multiple settings.^{1,2} Symptoms often extend into adulthood.³ Alternatively, ADHD-related traits can be conceptualized within the framework of neurogenetic diversity, reflecting natural variations in brain development that are not necessarily pathological. Certain characteristics associated with ADHD, such as heightened energy and creativity, may confer evolutionary advantages or situational benefits. This perspective is supported by growing evidence that ADHD traits exist on a spectrum of neurodivergence, with their impact—whether adaptive or challenging—shaped by environmental and societal contexts.^{4,5} Therefore, while ADHD is highly heritable, its symptomatology is shaped by gene-environment interactions, with environmental factors modulating genetic risks, even in strongly inherited cases.⁶ Dopamine and norepinephrine are key neurotransmitters implicated in its pathophysiology.⁷ Neuroimaging studies have identified structural brain abnormalities, notably in the prefrontal cortex, corpus striatum, and cerebellum.⁷ These structural, functional, and chemical changes may mediate the relationship between genetic and environmental risks, ADHD onset and progression, and associated impairments.⁸

Globally, ADHD affects an estimated 7.6 % of children aged 3–12 years and 5.6 % of adolescents aged 12–18 years.⁹ It is more commonly diagnosed in males (male-to-female ratio: 2:1–10:1),¹⁰ though recent evidence suggests underdiagnosis in females, likely due to their tendency to exhibit internalizing rather than externalizing behaviors and develop better coping strategies to manage ADHD-related challenges.¹¹ The economic impact of ADHD is substantial. In Europe, annual per-patient costs range from €9860 to €14,483, with national expenditures between €1041 and €1529 million.¹² In the United States, the societal cost of ADHD in childhood and adolescence is conservatively estimated at \$42.5 billion annually, ranging from \$36 billion to \$52.4 billion, based on a 5 % prevalence rate.¹³

Children and adolescents with ADHD are at greater risk for adverse outcomes, including academic underachievement, school dropout, low self-esteem,¹⁴ strained peer and family relationships, engagement in risky behaviors,² elevated perceived stress,¹⁵ and diminished health-related quality of life.² ADHD also increases the likelihood of substance misuse disorders by 1.5 times (2.4 times for smoking) and problematic media use by 9.3 times.¹⁶ Enuresis affects about 17 % of children with ADHD, while 25–70 % experience sleep disorders.¹⁶ ADHD is additionally linked to disordered eating in youth,¹⁶ traffic accidents, premature pregnancy, and antisocial behavior.¹⁴ However, evidence suggests that ADHD symptoms are a risk factor for antisocial behavior only in conjunction with other variables, such as substance use,¹⁷ negative parenting behaviors,¹⁸ or past arrests.¹⁷

Stimulants, including Methylphenidate and Amphetamines, are the primary treatment for ADHD. When these are ineffective or poorly tolerated, alternatives such as Atomoxetine, Guanfacine, and Clonidine, may be considered.¹⁹ Despite their efficacy, adverse effects (AEs) are common, with headache, abdominal pain, fatigue, insomnia, somnolence, and reduced appetite being the most frequently reported.²⁰ Additionally, not all patients respond to medication.²⁰ Other strategies, such as behavioral accommodations, cognitive training, neurofeedback, and brain stimulation are also employed.¹⁹ A systematic review has

demonstrated their effectiveness in enhancing cognitive functions, particularly inhibition and flexibility.²¹ Nevertheless, behavioral therapy for ADHD is often challenging for ongoing implementation and only partially activates the child's natural reward system.²² While neurofeedback may offer efficacy similar to stimulants, some studies indicate it is unsuitable as a standalone treatment for ADHD.²³

Complementary and alternative medicine (CAM) is increasingly sought after by parents of children with ADHD, often due to concerns over the side effects of pharmacological treatments or limited availability of behavioral therapies.²⁴ A systematic review of 12 original studies from various countries/regions revealed that CAM use among ADHD patients globally ranges from 7.5 % to 67.6 %, with over 60 % reporting lifetime CAM use.²⁵ Another study found that approximately 54 % of parents utilize one or more CAM modalities, including expressive therapies, vitamins, and dietary changes, to manage their children's symptoms.²⁶ Besides nutritional and mind-body therapies, acupuncture is also commonly employed.²⁷

Several systematic reviews and meta-analyses (SR/MAs) have evaluated acupuncture as a treatment for ADHD. Zhang *et al.* assessed five SR/MAs published between 2011 and 2021 using the AMSTAR-2 tool, revealing their methodological quality ranged from "Critically Low" to "Low," warranting caution in interpreting their conclusions.²⁸ A Cochrane SR/MA prior to 2011 failed to identify any eligible studies.²⁹ In response to this gap, our team conducted a systematic review with enhanced methodology, including original trials published after 2021. This review aimed to provide more reliable evidence on the efficacy and safety of acupuncture as an alternative or adjunctive treatment for ADHD, focusing specifically on children and adolescents while excluding adults.

2. Methods

2.1. Study registration

We performed this study following the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 Statement* guidelines.³⁰ A protocol was prospectively registered on the PROSPERO (Identifier: CRD42024603565).

2.2. Eligibility criteria

The PICOS framework was utilized to define the inclusion criteria and screen eligible trials.

Participant (P): Only children and adolescents clinically diagnosed with ADHD based on standardized diagnostic criteria (APPENDIX 1.1) were considered. Studies lacking formal diagnostic guidelines, even if they referenced ADHD or briefly described attention-deficit/hyperactivity symptoms, were excluded.

Intervention (I): Interventions were limited to traditional needle acupuncture (TNA), including manual- and electro- acupuncture, or TNA combined with conventional ADHD treatments (psychiatric drugs, behavioral/cognitive therapy, and/or neurofeedback). Trials incorporating laser acupuncture, auricular acupressure, or other modified acupuncture techniques were excluded due to their differing mechanisms,³¹ which could confound the assessment of TNA's true effects.

Comparator (C): Comparator interventions were restricted to waitlist-control, placebo-TNA, conventional care, or TNA/placebo-TNA combined with conventional treatments.

Outcome (O): The primary outcome included the Conners'

Hyperactivity Index (CHI), which can also be used as the Conners Abbreviated Symptom Questionnaire,³² and scores from other validated ADHD scales, such as the Conners' Parent Rating Scale (CPRS), Conners' Teacher Rating Scale (CTRS), and Swanson, Nolan, and Pelham Rating Scale (SNAP-IV). No version restrictions were applied for CPRS or CTRS. Secondary outcomes encompassed additional questionnaires or neuropsychological tests used to assess ADHD-related performance or intelligence, and AEs.

Study (S): Only formally published randomized controlled trials (RCTs) and non-randomized controlled clinical trials (NRCTs) with parallel designs were included.

2.3. Search strategy and data extraction

The search strategy was developed by all authors in collaboration with an academic librarian from Tongji University. Relevant studies published until November 2024 were identified through searches in databases including Cochrane CENTRAL, EMBASE, MEDLINE (via PubMed), CQVIP, Wanfang, CNKI, and SinoMed. Only English and Chinese literature were included. APPENDIX 1.2 shows the search strategies with search terms. Additional studies were retrieved from references cited in the included papers and existing SR/MAs.

Results were imported into EndNote 21 to remove duplicates. Titles and abstracts were initially screened to exclude irrelevant studies, with full texts reviewed as needed. Two reviewers (T-J and WJ-Z) independently assessed eligibility, achieving consensus on the final inclusion. A standardized data collection form was piloted, capturing key information from each eligible trial, including the first author, publication date, country/region, study design, grouping methods, sample size per group, ADHD duration, diagnostic criteria, Traditional Chinese Medicine (TCM) syndrome patterns, intervention protocols (e.g., dose, frequency, treatment course), control treatments, outcomes, results, follow-up, and AEs.

2.4. Evaluation of risk of bias in individual studies

Two reviewers (QQ-F and Y-X) independently assessed the included trials. Cohen's *Kappa* values were calculated to measure inter-rater agreement, and any disagreements were resolved through discussion, with arbitration by a third reviewer (YS-H). The methodological quality of RCTs was evaluated using the Revised Cochrane Risk of Bias Tool (ROB 2.0),³³ while the quality of NRCTs was appraised using the Cochrane Risk of Bias in Non-randomized Studies-of Interventions (ROBINS-I).³⁴

3. Data analysis

Each included study was qualitatively described for its characteristics and assessed for methodological quality prior to quantitative synthesis. For outcomes assessed in at least three trials, a meta-analysis was conducted using R 4.3.3 with the "meta" package (v7.0-0). Continuous variables (e.g., CHI, etc.) were pooled via the inverse variance method. Heterogeneity was evaluated with the *Chi*² test and quantified by the *I*² statistic. The random-effects model was applied by default, following Tufanaru et al.,³⁵ to generalize conclusions beyond the included studies. The fixed-effects model was only considered when no heterogeneity was observed. Trial Sequential Analysis (TSA) was utilized to assess the adequacy of sample sizes for primary outcomes (i.e., CHI), with a 5 % two-tailed type I error rate and 80 % power using TSA 0.9.5.10 Beta software.

Subgroup analyses were performed when significant clinical heterogeneity was present and the data permitted, considering study type (RCT Vs. NRCT), comparator interventions (medication Vs. behavioral therapy Vs. neurofeedback), study location (Mainland China Vs. other regions), and acupuncture dose (≥ 40 sessions Vs. < 40 sessions). We also conducted meta-regression analysis and sensitivity analysis if

sufficient studies were available ($n \geq 10$). Univariate or multivariate meta-regressions were conducted with covariates such as publication year, sample size, study type, study site, treatment dose, and control interventions. Sensitivity analysis using influence analysis was performed to test the robustness of the meta-synthesis conclusions. Potential publication bias for outcomes based on at least ten trials was assessed using linear regression (*Egger's test*) in STATA 18.0.

4. Assessment on the certainty of evidence

The overall quality of evidence obtained from the meta-synthesis was appraised using the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) framework.³⁶ The certainty of evidence was categorized into four levels, ranging from "High" to "Very Low".

5. Results

The initial search yielded 116 articles. Following duplicate removal and thorough full-text screening, 22 RCTs and three NRCTs, composing a total of 1758 participants from these 25 studies, met the predefined criteria (APPENDIX 2). Details of the excluded studies with reasons for ineligibility were listed in APPENDIX 3.

5.1. Description of studies

Of the 25 included trials, 20 were conducted in mainland China, while the remaining five took place in South Korea,³⁷ Canada,³⁸ Iran,³⁹ Hong Kong,⁴⁰ and Taiwan.⁴¹ Study designs varied: one trial used a waitlist control,³⁷ six compared acupuncture with psychiatric drugs (e.g., Methylphenidate, Atomoxetine, Haloperidol),⁴¹⁻⁴⁶ and others assessed acupuncture combined with conventional care versus conventional care alone. Conventional care included pharmacotherapy, behavioral therapy, neurofeedback, or their combinations. No studies directly compared acupuncture with placebo-/sham- acupuncture (APPENDIX 4).

CPRS and CHI were the most frequently used primary outcomes, reported in 15 and 16 trials, respectively. Other scales utilized to assess symptom changes included the SNAP-IV,^{40,41,47-49} the CTRS,³⁸ ADHD-Rating Scale,^{37,39} and IOWA-Conners Rating Scale.³⁷ Four studies^{47,50-52} employed Integrated Visual and Auditory Continuous Performance Test (IVA/CPT) modules, such as the Full Scale Attention Quotient (FSAQ), Full Scale Response Control Quotient (FSRCQ), Auditory Attention Quotient, and/or Visual Attention Quotient, to evaluate ADHD-related performance in children and adolescents. Three trials^{40, 41,53} also used the Combined Raven's Test, a modified Chinese version of Raven's Progressive Matrices,⁵⁴ as a secondary outcome to measure intelligence and abstract reasoning skills (APPENDIX 4).

Safety outcomes were reported in only eight trials,^{37,38,40,44,47,55-57} covering three interventions: acupuncture, Methylphenidate, and their combination. The AEs associated with these interventions are summarized in APPENDIX 5. The limited data indicated that acupuncture was generally safe, with AEs primarily including needling-site pain (10.3 %) and headache (6.5 %). In comparison, Methylphenidate was associated with a significantly higher frequency of AEs. Common AEs (≥ 5 % incidence) included loss of appetite, sleep disturbances, headache, abdominal pain, dry mouth, nausea and vomiting, constipation, palpitations, and sweating. When Methylphenidate was combined with acupuncture, the incidence of several AEs decreased: loss of appetite (13.8 to 4.5 %), sleep disturbances (10.2 to 1.4 %), dry mouth (5 % to 0), abdominal pain (5.1 % to 0), and constipation (5.1 % to 0). However, nausea, vomiting, and sweating rates remained largely unchanged, whereas palpitations increased from 5 % to 10 %.

5.2. Assessment of risk of bias (RoB) in individual studies

5.2.1. Quality of RCTs: moderate to high RoB

Among the 22 RCTs, all claimed to use randomized designs, but five studies did not specify the randomization method.^{45,46,50,57,58} Only two studies employed allocation concealment, such as sealed envelopes.^{39,41} Consequently, all other studies were rated as having "some concerns" in the "randomization process" domain of the ROB 2.0 tool. Baseline checks were conducted in all trials to ensure balance between intervention and control groups; however, 21 trials did not implement blinding, leading to "some concerns" in the "deviations from intended interventions" domain. Only one trial³⁹ was rated as low RoB in this domain, as blinded participants could not distinguish between acupuncture and placebo-acupuncture. This trial³⁹ also received a low RoB rating in the "outcome measurement" domain due to blinded assessors. In contrast, the remaining studies, lacking detailed descriptions of blinding procedures, were rated as having "some concerns" in this domain.

Five RCTs reported dropouts.^{37,39,44,45,51} Among these, only one trial³⁷ employed an Intention-to-Treat (ITT) analysis and was rated as low RoB in the "missing outcome data" domain. Three trials^{44,45,51} had "some concerns" in this domain due to acceptable dropout rates (5%-5.7%) despite not using ITT analysis. One trial³⁹ was rated as high RoB in this domain, as 90 patients were enrolled, but only 59 completed the study, and data analysis excluded dropouts, introducing potential

bias. Fifteen trials^{39,41-43,45,46,48-52,58-61} were rated as high RoB in the "selective reporting outcome" domain due to the absence of reported safety outcomes.

Overall, all trials, except for seven RCTs^{37,40,44,47,55-57} rated as having "some concerns," were classified as having high RoB (see Fig 1A and B). The assessment procedure achieved substantial agreement ($Kappa = 0.83$).

5.2.2. Quality of NRCTs: moderate to high RoB

Three NRCTs^{38,53,62} were rated low RoB in "participant selection" and "confounding" domains due to the use of standardized diagnostic guidelines, ensuring baseline balance and preventing crossover between interventions. All participants completed the interventions, with clear methods that adhered to the intended protocols, and no misclassification of intervention status was observed. These trials were thus rated low RoB in the "missing data," "deviations from intended interventions," and "intervention classification" domains.

However, none reported measures to control for measurement or observer bias, leaving the blinding of outcome assessors uncertain. Two trials^{53,62} had serious risk in "selective reporting outcome" due to the absence of post-intervention safety outcomes. One trial³⁸ had moderate risk, as it reported AEs without specifying their incidence.

Overall, one NRCT³⁸ had moderate RoB, while the other two^{53,62} were classified as having serious RoB (see Fig 1C and D). The assessment

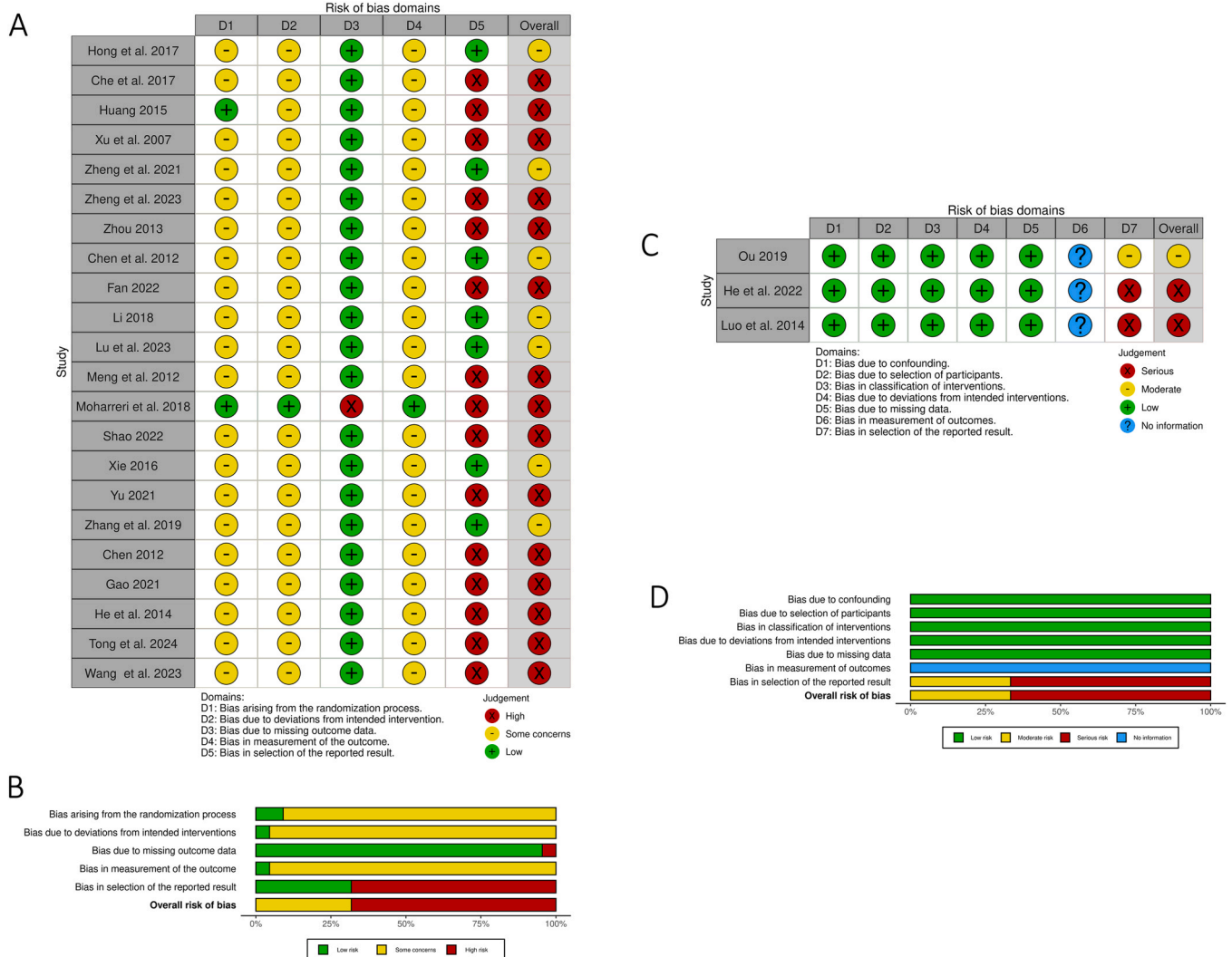


Fig. 1. The Risk of Methodological Bias in the Included Studies. (A) Risk of Bias Summary for RCTs. (B) Risk of Bias Graph for RCTs. (C) Risk of Bias Summary for NRCTs. (D) Risk of Bias Graph for NRCTs. RCTs, Randomized Controlled Clinical Trials; NRCTs, Non-Randomized Controlled Clinical Trials.

showed strong agreement ($Kappa = 0.91$).

5.3. Analyses of outcome measures

5.3.1. Acupuncture Vs. waitlist control or placebo/sham-acupuncture

One RCT (*participants* = 93) compared acupuncture with a waitlist control.³⁷ The study found no significant differences between the groups in ADHD-Rating Scale, IOWA-Conners Rating Scale, CPRS, or Child Behavior Checklist scores after a six-week acupuncture intervention. However, participants undergoing acupuncture outperformed the waitlist group on several modules of the Computerized Neurocognitive Function Test, including the backward digit span, backward visual span, and auditory continuous performance tests. These results suggest that while acupuncture did not significantly alleviate ADHD symptoms, it improved cognitive function, including working memory and auditory response control. Acupuncture was also deemed safe, with only mild, self-limiting headaches reported by three participants, none of whom withdrew from the study.³⁷

5.3.2. Acupuncture Vs. Conventional Care

This category included six studies (*participants* = 415), with five using Methylphenidate and one using Haloperidol as the positive control. None compared acupuncture with non-pharmacological standard care. Meta-analyses were performed for CHI and CPRS.

5.3.2.1. CHI. Five trials (*participants* = 347) compared acupuncture with psychiatric drugs. Pooled analysis showed acupuncture was more effective in reducing CHI [$MD = -4.98$, 95% $CI (-5.27, -4.70)$, $p < 0.01$], with no heterogeneity ($I^2 = 0$) (see Fig. 2). The Z-curve for CHI exceeded the traditional boundary but did not cross the TSA boundary, and the accumulated information fell short of the required information size (*RIS*). This indicated that the conventional meta-analysis may have yielded a false positive, and additional sample size were needed to validate the current findings (APPENDIX 6).

5.3.2.2. CPRS. Three trials (*participants* = 207) compared acupuncture with Methylphenidate across different CPRS subsets. Acupuncture was more effective in reducing *Impulsive/Hyperactive* domain scores [$SMD = -1.71$, 95% $CI (-2.08, -1.35)$, $p < 0.01$], but no significant differences were found for *Conduct Problems* [$SMD = 0.03$, 95% $CI (-0.93, 0.99)$, $p = 0.95$] or *Learning Problems* [$SMD = 0.29$, 95% $CI (-0.38, 0.97)$, $p = 0.39$] domain scores (see Fig 3A, B and C).

5.3.3. Acupuncture Combined with Conventional Care Vs. Conventional Care

A total of 18 studies addressed this comparison. Eleven trials assessed the efficacy of acupuncture combined with Methylphenidate/Atomoxetine versus medication alone; six trials compared acupuncture combined with neurofeedback/behavioral therapy versus neurofeedback/behavioral therapy alone; and one trial evaluated acupuncture combined with behavioral therapy and Methylphenidate versus behavioral therapy and Methylphenidate alone. Meta-analyses were performed for CHI, CPRS, SNAP-IV, and IVA-CPT.

5.3.3.1. CHI. Eleven trials (*participants* = 707) compared CHI between acupuncture combined with conventional care and conventional care alone. Meta-analysis favored the combination therapy in reducing CHI [$SMD = -1.21$, 95% $CI (-1.88, -0.54)$, $p < 0.01$] (see Fig. 4). The Z-curve for CHI in TSA exceeded the *RIS* ($n = 373$), confirming that the sample size was adequate for producing the current results (APPENDIX 7).

Subgroup analyses were performed due to high heterogeneity. Acupuncture added to psychiatric drugs or neurofeedback resulted in more significant reductions in CHI [$SMD = -0.88$, 95% $CI (-1.35, -0.41)$, $p < 0.01$ for “Vs. psychiatric drugs”; $SMD = -2.88$, 95% $CI (-5.51, -0.26)$, $p = 0.03$ for “Vs. neurofeedback therapy”]. However, no significant difference was observed between behavioral therapy alone and behavioral therapy combined with acupuncture [$SMD = -0.79$, 95% $CI (-2.04, 0.45)$, $p = 0.21$]. In NRCTs, no significant difference was found between the combination therapy and conventional care alone in reducing CHI [$SMD = -0.71$, 95% $CI (-2.11, 0.69)$, $p = 0.32$], while RCTs tended to favor the combination therapy [$SMD = -1.30$, 95% $CI (-1.87, -0.72)$, $p < 0.01$]. This discrepancy might be due to patient preferences and emotional factors influencing outcomes in NRCTs. A significant interaction effect was identified in the acupuncture dosage subgroup (Chi^2 statistic 5.25, $df = 2$, $p = 0.02$), though heterogeneity remained unexplained (APPENDIX 8).

Meta-regression indicated a potential weak association between heterogeneity and conventional care in the control group ($I^2 = 91.22\%$, $Tau^2 = 0.82$, $p = 0.04$), while factors such as study sample size ($I^2 = 90.57\%$, $Tau^2 = 1.35$, $p = 0.84$), publication year ($I^2 = 89.45\%$, $Tau^2 = 0.94$, $p = 0.09$), study type ($I^2 = 53.74\%$, $Tau^2 = 0.09$, $p = 0.59$), study site ($I^2 = 93.75\%$, $Tau^2 = 1.15$, $p = 0.26$) and treatment dose ($I^2 = 88.26\%$, $Tau^2 = 0.88$, $p = 0.07$) did not significantly contribute to heterogeneity (APPENDIX 9).

Sensitivity analysis provided additional validation of the overall robustness of the results (APPENDIX 10).

5.3.3.2. CPRS. Ten trials (*participants* = 667) compared CPRS global scores and/or subdomain scores between acupuncture combined with conventional care and conventional care alone. Pooled analysis favored the combination therapy in reducing CPRS global scores [$SMD = -2.33$, 95% $CI (-3.03, -1.63)$, $p < 0.01$]. The combination therapy also significantly decreased scores in the *Impulsive/Hyperactive* domain [$SMD = -1.39$, 95% $CI (-2.09, -0.70)$, $p < 0.01$], *Conduct Problems* domain [$SMD = -0.97$, 95% $CI (-1.47, -0.48)$, $p < 0.01$], *Psychosomatic* domain [$SMD = -0.90$, 95% $CI (-1.69, -0.11)$, $p = 0.03$], and *Learning Problems* domain [$SMD = -1.11$, 95% $CI (-1.78, -0.43)$, $p < 0.01$]. No significant difference was found for the *Anxiety* domain scores [$SMD = -0.59$, 95% $CI (-1.37, 0.20)$, $p = 0.14$] (see Fig 5A, B, C, D, E and F).

Subgroup analyses revealed that for reducing *Psychosomatic* domain scores, low-dose acupuncture (< 40 sessions) combined with conventional care was not superior to conventional care alone [$SMD = -0.44$, 95% $CI (-1.02, 0.14)$, $p = 0.14$], whereas high-dose acupuncture (≥ 40 sessions) was more effective than conventional care alone [$SMD = -1.63$, 95% $CI (-3.10, -0.16)$, $p = 0.03$]. Acupuncture combined with psychiatric drugs did not outperform psychiatric drugs alone [$SMD = -0.90$, 95% $CI (-1.79, -0.01)$, $p = 0.05$]. In reducing *Learning Problems* domain

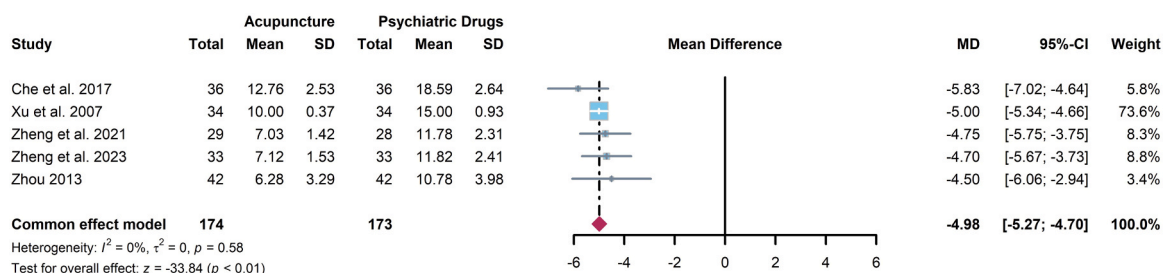
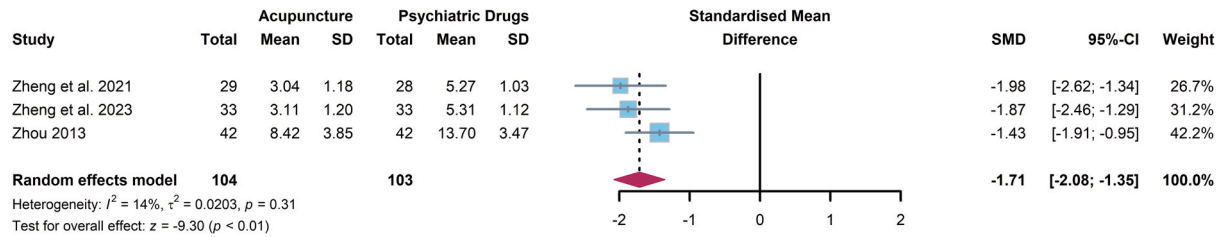
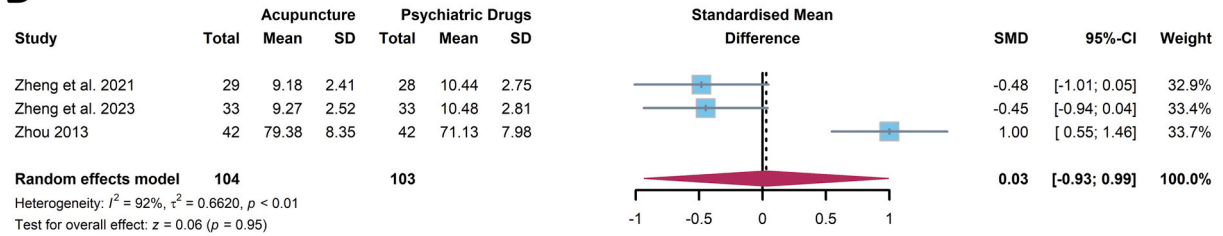


Fig. 2. Forest Plots of CHI (Acupuncture Vs. Conventional Care). CHI, Conners' Hyperactivity Index.

A



B



C

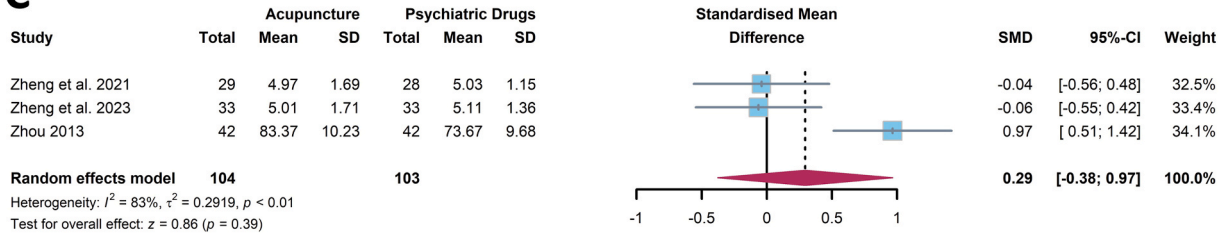


Fig. 3. Forest Plots of CPRS Subsets (Acupuncture Vs. Conventional Care). (A) Forest Plots of CPRS Impulsive/Hyperactive domain. (B) Forest Plots of CPRS Conduct Problems domain. (C) Forest Plots of CPRS Learning Problems domain. CPRS, Conners' Parent Rating Scale.

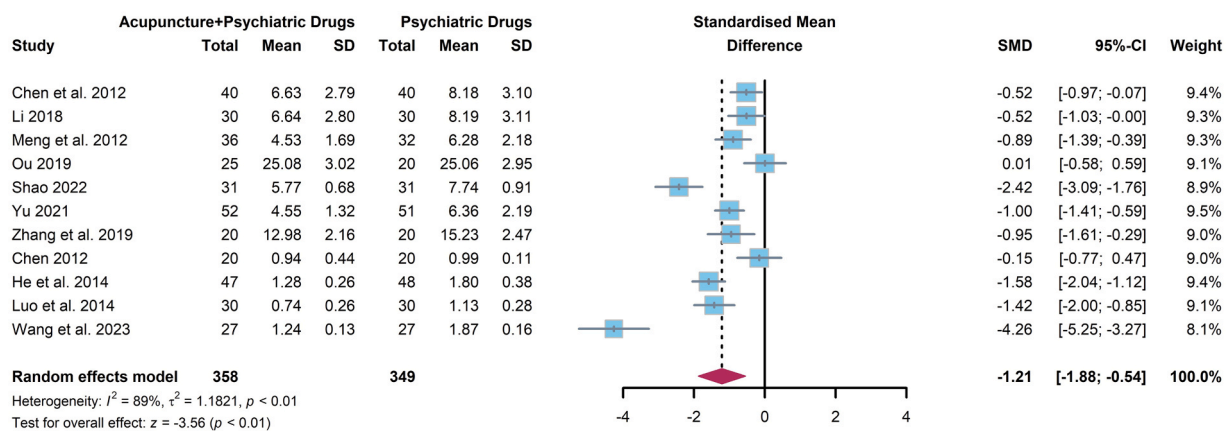


Fig. 4. Forest Plots of CHI (Acupuncture Combined with Conventional Care Vs. Conventional Care). CHI, Conners' Hyperactivity Index.

scores, acupuncture combined with psychiatric drugs outperformed psychiatric drugs alone [$SMD = -1.27$, 95 %CI (-2.01, -0.52), $p < 0.01$], while acupuncture combined with behavioral therapy showed no advantage over behavioral therapy alone [$SMD = -0.77$, 95 %CI (-2.48, 0.94), $p = 0.38$]. Significant interaction effects were observed in the Impulsive/Hyperactive (Chi^2 statistic 27.54, $df = 2$, $p < 0.01$) and Conduct Problems (Chi^2 statistic 7.33, $df = 2$, $p = 0.03$) domains, though heterogeneity remained unexplained (APPENDIX 11).

5.3.3.3. SNAP-IV. Three trials (participants = 236) compared acupuncture combined with conventional care to conventional care alone across SNAP-IV subsets. Pooled results indicated that combination therapy resulted in greater reductions in scores of Inattention domain [$SMD = -0.96$, 95 %CI (-1.52, -0.40), $p < 0.01$], Hyperactivity/Impulsivity domain [$SMD = -1.08$, 95 %CI (-1.62, -0.53), $p < 0.01$] and Opposition/Defiance domain [$SMD = -1.17$, 95 %CI (-1.88, -0.46), $p < 0.01$] (see Fig 6A, B and C).

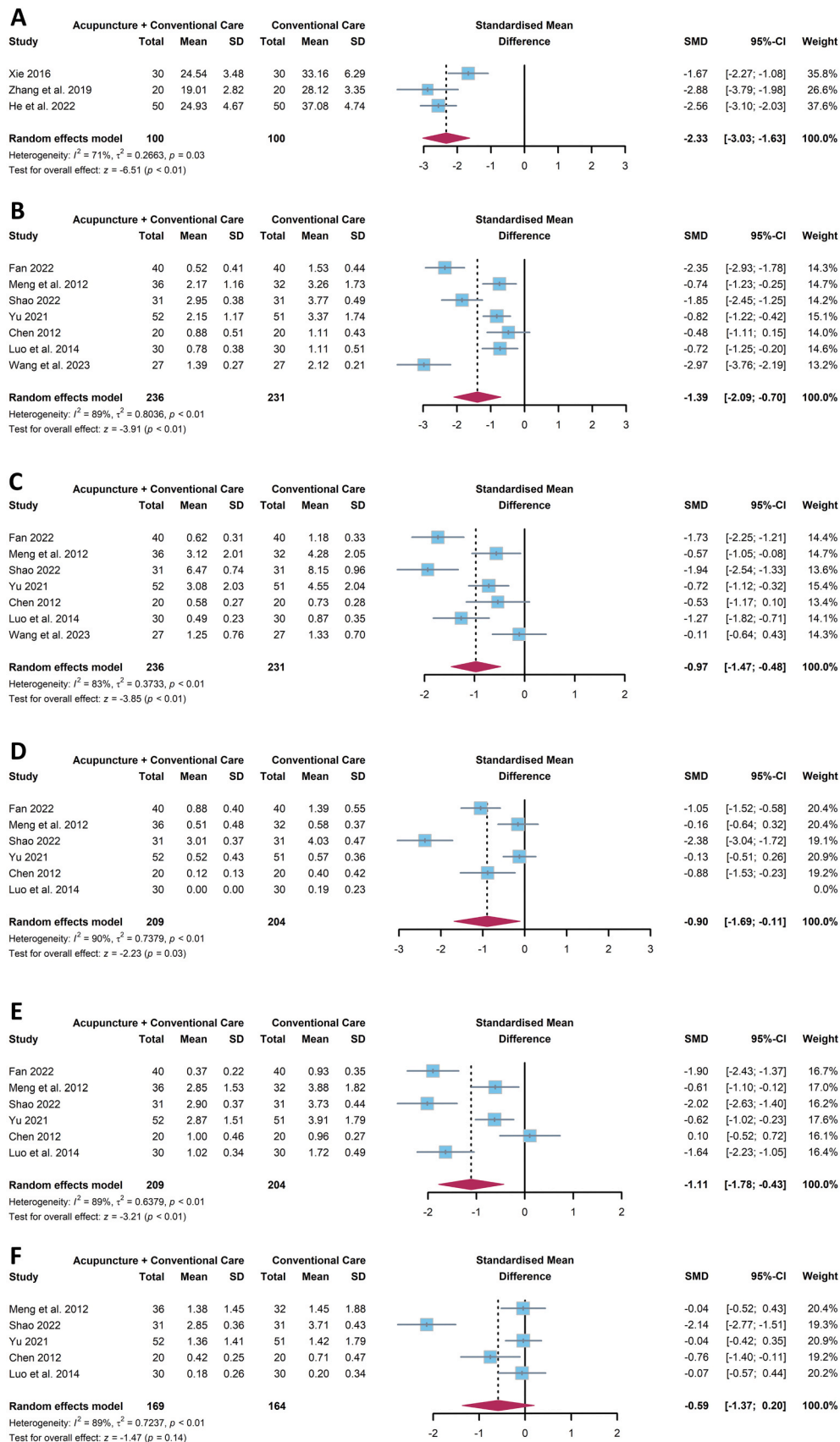


Fig. 5. Forest Plots of CPRS Global Scores and Subsets (Acupuncture Combined with Conventional Care Vs. Conventional Care). (A) Forest Plots of CPRS Global Scores. (B) Forest Plots of CPRS Impulsive/Hyperactive domain. (C) Forest Plots of CPRS Conduct Problems domain. (D) Forest Plots of CPRS Psychosomatic domain. (E) Forest Plots of CPRS Learning Problems domain. (F) Forest Plots of CPRS Anxiety domain. CPRS, Conners' Parent Rating Scale.

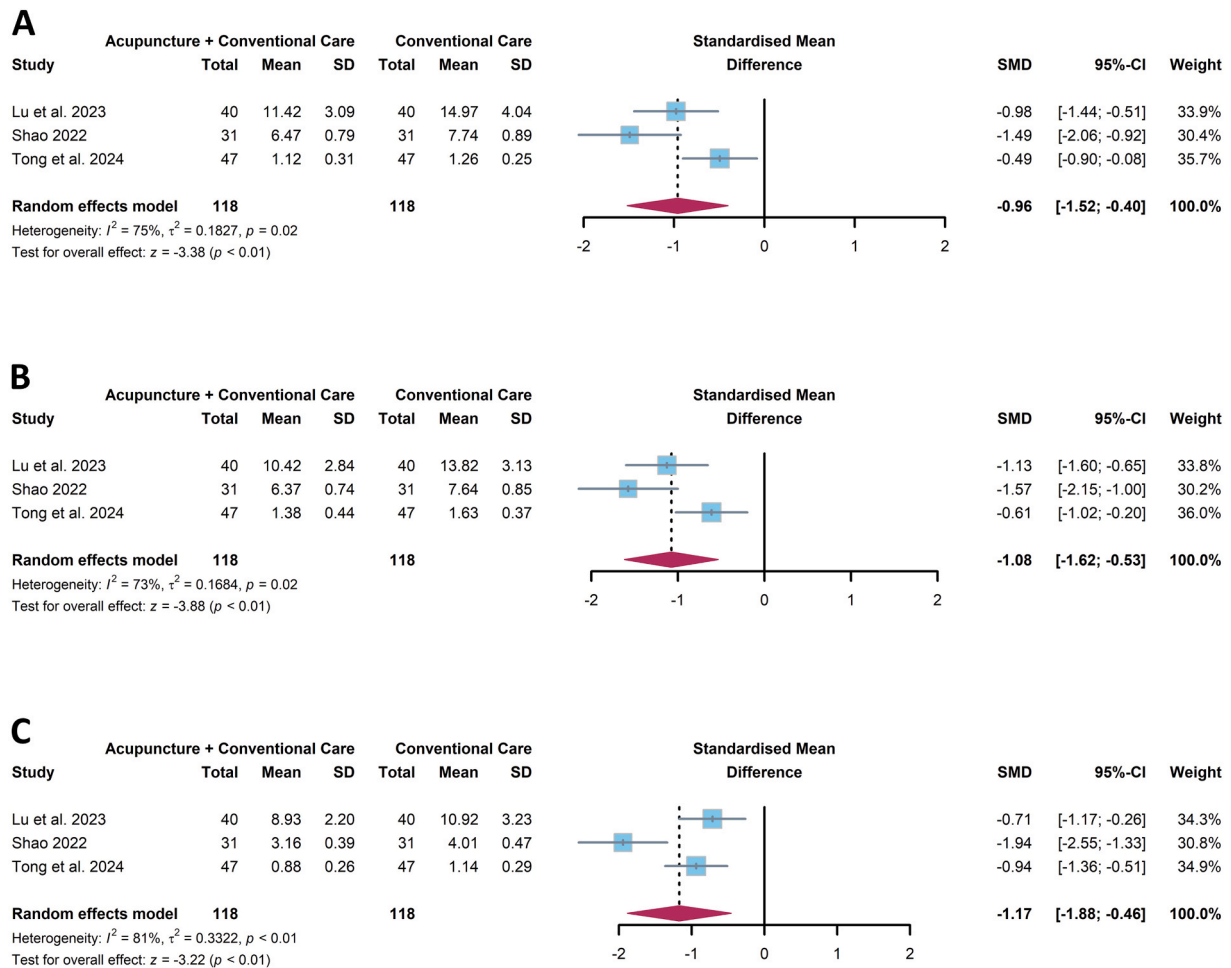


Fig. 6. Forest Plots of SNAP-IV Subsets (Acupuncture Combined with Conventional Care Vs. Conventional Care). (A) Forest Plots of SNAP-IV Inattention domain (B) Forest Plots of SNAP-IV Hyperactivity/Impulsivity domain. (C) Forest Plots of SNAP-IV Opposition/Defiance domain. SNAP-IV, Swanson, Nolan, and Pelham Rating Scale.

5.3.3.4. IVA-CPT. Four studies (*participants* = 299) measured FSAQ and FSRCQ subsets of IVA-CPT. The results favored the combination therapy in increasing FSAQ [$SMD = 0.83$, 95 %CI (0.59, 1.06), $p < 0.01$] and FSRCQ [$SMD = 0.82$, 95 %CI (0.56, 1.09), $p < 0.01$] scores (see Fig 7A and B).

5.4. Publication bias test

We conducted a publication bias test based on CHI scores (APPENDIX 12). The results revealed well-balanced distribution around the central line, with no evidence of significant publication bias detected ($p = 0.11$)

5.5. Certainty and quality of evidence

The certainty and quality of evidence of 16 outcomes were summarized in APPENDIX 13. As per the GRADE system, 11 outcomes were rated as "Very Low" and five as "Low". The predominant reasons for downgrading the evidence quality included substantial RoB in the included trials and high heterogeneity. The reliance on NRCTs rather than RCTs further contributed to initial downgrade.

6. Discussion

6.1. Summary of findings

The CPRS was extensively utilized in acupuncture-related ADHD studies. Acupuncture alone significantly reduced *Impulsive/Hyperactive* domain scores compared to Methylphenidate, with similar effects on *Conduct* and *Learning* domains. Acupuncture was also more effective than pharmacotherapies like Methylphenidate, Haloperidol, and Atomoxetine in reducing CHI. However, TSA indicated this may be a false positive due to inadequate sample sizes. No studies directly compared acupuncture with behavioral therapy.

Acupuncture combined with medication was superior to medication alone in the *Learning* domain, while acupuncture combined with behavioral therapy outperformed behavioral therapy alone in the *Psychosomatic* domain. In the *Impulsive/Hyperactive* and *Conduct* domains, acupuncture combined with either medication or behavioral therapy showed better outcomes than either treatment alone. However, acupuncture did not provide additional benefits in the *Anxiety* domain. It also significantly reduced scores of SNAP-IV and IVA-CPT subsets when integrated with conventional care. Acupuncture was well-tolerated, with mild side-effects like needle-site pain and headaches. Acupuncture combined with Methylphenidate reduced medication-related AEs, including appetite loss, sleep disturbances, dry mouth, and abdominal pain.

In summary, acupuncture combined with conventional care was

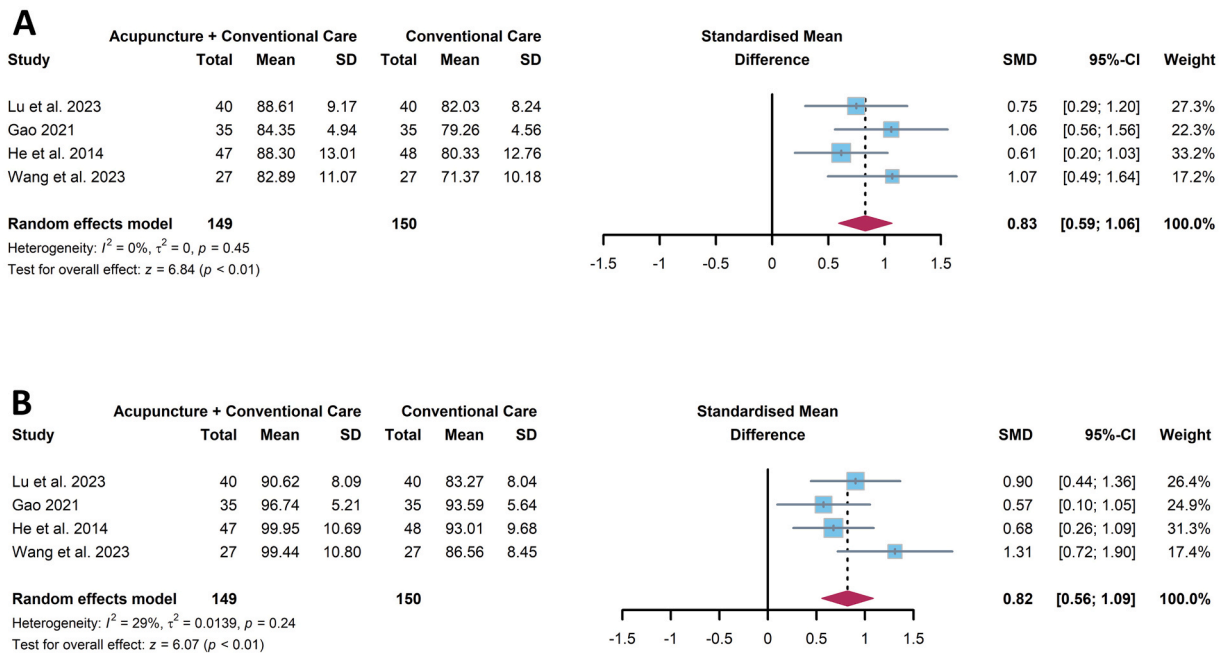


Fig. 7. Forest Plots of IVA-CPT Subsets (Acupuncture Combined with Conventional Care Vs. Conventional Care). (A) Forest Plots of IVA-CPT FSAQ domain (B) Forest Plots of IVA-CPT FSRQC domain. IVA/CPT, Integrated Visual and Auditory Continuous Performance Test; FSAQ, Full Scale Attention Quotient; FSRQC, Full Scale Response Control Quotient.

more effective and safer than pharmacotherapy in ameliorating impulsivity, hyperactivity, inattention, and/or conduct symptoms in ADHD. Additional benefits were seen in improving learning difficulties when combined with medication and psychosomatic symptoms when combined with behavioral therapy. Nonetheless, the quality of evidence supporting these findings was poor due to methodological flaws in most studies.

6.2. Strengths, limitations, and comparison with previous SR/MAs

Four Chinese⁶³⁻⁶⁶ and four English^{29,67-69} SR/MAs have investigated the effects of acupuncture on ADHD. However, these reviews included studies with unclear diagnostic systems, trials involving other CAM interventions such as Chinese herbal medicine or auricular acupressure, and studies lacking internationally recognized ADHD scales or neuropsychological test. This inclusion of non-standard trials introduced extra variability that complicated result interpretation. Furthermore, five SR/MAs were published over five years ago.^{29,63,64,66,67} Even the most recent SR/MA,⁶⁹ published in February 2023, included only 14 trials, with several outcome measures based on just two trials, which reduced statistical power and reliability. In contrast, our study employed a more robust methodology with key improvements: (1) broader trial inclusion through updated retrieval and reduced variability via stricter selection criteria; (2) novel inclusion of IVA/CPT, an objective ADHD diagnostic and assessment tool,⁷⁰ addressing the limitations of prior reviews that relied solely on questionnaires; (3) inclusion of SNAP-IV, not analyzed in previous SR/MAs; and (4) the adoption of TSA, a technique absent in earlier reviews as well, enabled the assessment of sample size adequacy and the identification of potential false-positive results.

Some limitations should be noted. First, the low methodological quality of the included trials undermined evidence reliability. Second, despite sensitivity, subgroup, and meta-regression analyses, high heterogeneity remained not fully explained. However, excluding low-quality trials was not justified, as prior methodological research warned against this due to the unclear distinction between high- and low-quality evidence.⁷¹ Third, two trials were conducted in South Korea

and Iran, raising the possibility that trials published in languages other than Chinese or English were overlooked, potentially impacting the current conclusions. Fourth, one of the included studies⁴³ utilized Haloperidol as the positive control. Although some studies suggest it may alleviate hyperactivity⁷² and unsocialized aggressive behaviors⁷³ in children with ADHD, it is banned in European countries like the UK and France for use in children under six years old.⁷⁴ Furthermore, as Haloperidol is not a first-line treatment for ADHD, its suitability as a control intervention in acupuncture studies remains uncertain. Nevertheless, the small sample size of this study likely had a negligible impact on the overall robustness of the meta-analysis results. Finally, due to the lack of high-quality RCTs comparing acupuncture with placebo-/sham-acupuncture, it remained unclear whether acupuncture was an ideal alternative for ADHD, let alone determining whether its effects were specific or placebo-driven. This evidence gap renders evidence-based recommendations for or against acupuncture in ADHD clinical settings impractical.

6.3. Interpretation of findings

Due to the significant AEs of medications, behavioral modification seemed a more favorable treatment option. However, in practice, challenges such as cost, limited access to treatment, and high dropout rates in family-based behavior therapy for children and adolescents with ADHD persisted.⁷⁵ Logistical barriers, including transportation and scheduling difficulties, further hindered parental engagement.⁷⁵ These predicaments in standard care leave room for the exploration of the potential benefits of various CAM, including acupuncture.⁷⁶

The mechanisms underlying acupuncture's effects on ADHD remained unclear,³⁷ but it likely operated through multiple pathways. Hori *et al.* reported that acupuncture significantly reduced activity in the dorsomedial prefrontal cortex, a region implicated in several psychiatric disorders, including ADHD, due to its overactivity.⁷⁷ Chinese researchers proposed that acupuncture's benefits for ADHD might have involved modulation of neurotransmitters in the prefrontal cortex.⁷⁸ Their study showed that acupuncture decreased hyperactivity and impulsivity in spontaneously hypertensive rats, a widely used ADHD

model, while enhancing learning and memory. These effects were accompanied by increased norepinephrine and serotonin levels in the prefrontal cortex.⁷⁸ This mechanism mirrored the action of medications such as Methylphenidate and Atomoxetine, which alleviated ADHD symptoms and comorbidities by boosting dopamine and norepinephrine levels in the prefrontal cortex.⁷⁹ Furthermore, the serotonin system was proposed to play a role in regulating hyperactivity, with chronic deficits of serotonin potentially triggering ADHD symptoms.⁸⁰

Unlike the widespread used CPRS, only six reviewed trials incorporated the IVA/CPT or Computerized Neurocognitive Function Test. While subjective measures are reliable and valid, the absence of objective outcome measures in ADHD research might lead to disputes, like parental placebo effects.⁸¹ Given that children, including those with ADHD, spend more time in school than at home, parents may lack comprehensive data to accurately assess their child's symptom changes.³⁷ Additionally, the elevated stress levels commonly experienced by parents of children with ADHD may distort their interpretation of children's symptoms, making it difficult to assess acupuncture's effects accurately.³⁷ Objective measures, less prone to rater bias and error, provide more reliable and replicable results.⁸² Thus, future clinical trials should incorporate objective tools like the IVA/CPT, the Quantified Behavior Test for children aged 6–12, and the Test Battery of Attention⁸² alongside ADHD questionnaires to more accurately quantify acupuncture's efficacy.

TCM therapies, including acupuncture, have been routinely integrated with conventional care for mental illness treatment in China, forming a well-established therapeutic model.⁸³ While this approach remained less prevalent in Western countries, our findings highlighted China's experience, offering valuable insights for policymakers considering the WHO's recommendation to incorporate CAM into conventional healthcare systems.⁸⁴ Subgroup analyses revealed context-specific benefits of acupuncture. For psychosomatic symptoms, combining acupuncture with behavioral therapy yielded superior outcomes compared to behavioral therapy alone, whereas its addition to psychiatric medication provided no significant advantage. Conversely, for learning difficulties, acupuncture enhanced the efficacy of psychiatric medication but showed no advantage when combined with behavioral therapy. These results suggest that acupuncture could serve as a strategic adjunct to behavioral therapy for psychosomatic symptoms and to medication for learning challenges, with limited effectiveness in other combinations. For hyperactivity, impulsivity, and conduct problems, acupuncture consistently improved outcomes across treatment modalities. When paired with medication, it also reduced drug-related AEs. Additionally, acupuncture addressed the high costs and adherence challenges associated with behavioral therapies,⁸⁵ providing a more accessible alternative. Notably, behavioral therapy showed limited effectiveness for inattention symptoms,⁸⁵ a gap acupuncture appeared to fill. Meta-synthesis of SNAP-IV *Inattention* (Fig. 6A) and IVA-CPT *FSAQ* (Fig. 7A) domain data further confirmed significant attention improvements when acupuncture was combined with conventional care. These findings underscored acupuncture's potential as a complementary strategy for enhancing ADHD treatment outcomes by targeting diverse core symptom profiles.

While acupuncture has shown promise in managing ADHD, several reliability concerns must temper the interpretation of these findings. First, a previous SR/MA highlighted a 12 % dropout rate in acupuncture RCTs,⁸⁶ whereas our analysis revealed that 80 % of the included studies reported no attrition, an atypical result for mental disorders-related clinical trials.⁸⁷ Second, although blinding acupuncturists posed challenges, blinding participants and assessors was both feasible and essential to minimize bias in intervention and outcome assessments. Yet, only two trials implemented adequate allocation concealment or blinding. Third, the absence of preregistration in 23 trials compromised transparency and impeded replication efforts,⁸⁸ emphasizing the need for future studies to prioritize prospective registration and protocol submission. Finally, only 12 % of the reviewed trials included follow-up,

limiting the ability to assess the medium- to long-term efficacy and safety of acupuncture in ADHD. Unlike medications, which typically produce rapid effects, acupuncture's benefits unfold gradually.³⁷ Evidence suggested that even a three-week follow-up was insufficient to capture its full impact on ADHD symptoms.³⁹ Furthermore, designs lacking extended follow-up failed to address the persistent and resistant nature of ADHD symptoms. Data from a UK cohort demonstrated a notable decline in medication adherence during adolescence and adulthood, particularly after age 15, despite ongoing symptoms. Poorly managed ADHD symptoms not only impaired the affected individuals but also imposed negative repercussions on their families and society.⁸⁹

Future research should also address the following areas. First, acupuncture dose parameters (e.g., treatment frequency, needle retention duration, and session intervals) are critical for therapeutic efficacy.⁹⁰ However, the included trials exhibited substantial heterogeneity in dosing protocols, ranging from two sessions per week for six weeks to five sessions per week for 24 weeks. Identifying a minimum threshold dose to maximize the cost-effectiveness of acupuncture for ADHD is thus of paramount clinical importance. Second, the variability in acupuncture response rates across ADHD subtypes and age groups remains poorly understood. Elucidating differential treatment benefits among ADHD populations is essential for evidence-based decision-making. Lastly, given cultural and ethnic variations, the applicability of acupuncture in Western pediatric and adolescent ADHD populations should be further validated, as only one included study was conducted outside Asia (Canada).³⁸

7. Conclusion

Acupuncture alone demonstrated greater efficacy than psychotropic medications in managing hyperactivity and impulsivity in children and adolescents with ADHD, though insufficient sample sizes cast doubt on whether these findings were false positives. Combining acupuncture with medication offered a safer alternative while reducing Methylphenidate-associated AEs. Whether combined with medication or behavioral therapy, acupuncture outperformed these treatments alone in improving inattention and conduct problems. However, its additional benefits for learning difficulties were evident only when combined with medication, and for psychosomatic issues, only when paired with behavioral therapy. Therefore, for children and adolescents with ADHD who were undergoing medication or behavioral therapy, particularly those with prominent symptoms of hyperactivity/impulsivity, inattention, and/or conduct problems, adding acupuncture to the standard care regimen targeting specific symptoms might enhance efficacy, reduce AEs, and improve treatment accessibility. Unfortunately, the quality of the trials endorsing these positive speculations was poor, and thus, the current evidence remained insufficient to strongly recommend acupuncture as a treatment in ADHD management.

Funding statement

This work was supported by the Health and Medical Research Fund, Health Bureau, Hong Kong SAR [20212801] and the Chinese Medicine Development Fund, Hong Kong SAR [23B2/030A] to YS-H; and Scientific Research Fund Project of Shanghai Sanda University [2024BSZX03] to FY-Z.

CRediT authorship contribution statement

Chow Chin-Moi: Writing – review & editing, Supervision, Project administration. **Ho Yuen-Shan:** Writing – review & editing, Supervision, Funding acquisition. **Fu Qiang-Qiang:** Writing – review & editing, Software, Methodology. **Kennedy Gerard A.:** Writing – review & editing, Supervision. **Conduit Russell:** Writing – review & editing, Validation. **Zhao Fei-Yi:** Writing – original draft, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Xu Yan:** Writing –

review & editing, Investigation, Formal analysis. **Xu Peijie:** Writing – review & editing, Visualization, Data curation. **Zhang Wen-Jing:** Writing – review & editing, Formal analysis. **Jiang Ting:** Writing – review & editing, Investigation, Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ctim.2025.103163.

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