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Article

Mind-Body Exercises (Yoga/Tai Chi) for Attention-Deficit/Hyperactivity Disorder: A Quantitative Evidence of Experimental Studies

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Abstract: Background: Attention-deficit/hyperactivity disorder (ADHD) is a common pediatric psychiatric disorder. Although mindful exercises (Yoga and Tai Chi) have been increasingly accepted as alternative medicine for ADHD, no meta-analytic review has been conducted on this topic. **Objective:** We systematically and critically evaluated the existing literature regarding the effects of the two most widely practiced mindful exercises on ADHD symptoms and social problems in children and adolescents with ADHD. **Methods:** Searching literature databases included PubMed, Web of Science, Scope, China National Knowledge Infrastructure and Wanfang. Only randomized controlled trials (RCT) and non-randomized controlled studies (NRS) that investigated the beneficial effects of Yoga and/or Tai Chi for ADHD were included in this review. Two review authors independently performed literature search, data extraction, and study quality assessment. Based on the random-effect model, standardized mean difference (SMD) reflects magnitude of mindful exercises was calculated. **Results:** Seven eligible studies (5 RCTs and 2 NRS) were included for meta-analysis. As compared to control groups, mindful exercises showed significant positive effects on attention (SMD = 0.93, 95% CI 0.39 to 1.48, $p < 0.001$, I2 = 36%), hyperactivity/impulsivity (SMD = 0.93, 95% CI 0.53 to 1.34, $p < 0.001$, I2 = 60.17%), overall symptoms of ADHD (SMD = 0.84, 95% CI 0.3 to 1.38, $p < 0.05$, I2 = 54.61%), and social problems (SMD = 0.49, 95% CI −0.01 to 0.98, $p < 0.05$, I2 = 0%). **Conclusions:** Yoga and Tai Chi may have the potential to alleviate the symptoms and social problems among children and adolescents with ADHD. More robust studies with large sample sizes are needed to validate results of the present meta-analytical review.

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Keywords: Tai Chi; Yoga; mindful exercise; ADHD; attention deficit; hyperactive disorder

1 Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a common pediatric developmental disorder, with its global estimate of prevalence that has reached to approximately 7.2% among children and adolescents [1]. Compare to typically developing children/adolescents, peers with ADHD have demonstrated deficient motor and cognitive control, excessive distractibility (mind wandering) and impulsivity, and low frustration tolerance [2]. A recent 16-year prospective study that followed children with ADHD into adulthood showed the persistence of ADHD symptoms was 60% [3]. Relatedly, it is increasingly accepted that children and adolescents with ADHD are closely associated with academic underachievement, reduced social and occupational opportunities, and impaired parent-children relationships [4]. Since its pathological mechanism remains elusive, no curative treatments for ADHD existed [5].

Evidence-based treatments that are beneficial for symptomatic management include stimulant medications and behavioral intervention strategies (e.g., parent training, peer teaching, adherence to rules, and reward stimuli) [6]. Although stimulant medications can successfully reduce some of the ADHD symptoms, their adverse effects including anorexia, irritability, abdominal pain, and sleep disturbance are frequently reported [7,8]. Moreover, most of behavioral interventions are time-consuming and need to integrate with stimulant medications in order to maximize positive effects [9]. Thus, searching for other alternative treatments for ADHD are highly encouraged in clinical settings [10]. For example, Yoga and Tai Chi (YGTC) as alternative medicine have been extensively investigated [11–16] and shown to be effective in improving cognitive [17–20] and emotional control [21–23] in different clinical populations.

YGTC are commonly considered and practiced as mindful exercise, which emphasizes an integration of mind-body connection [24–27]. More specifically, YGTC involves relatively slow-pace muscular activity coupled with mental focus, breathing control, kinesthetic body awareness, and meditative state of mind [28]. These unique features may provide children with ADHD with the opportunity to cultivate mental skills (e.g., attention, cognitive and emotional self-control, and mindfulness) [29]. Furthermore, a meta-analysis indicated that mindful exercises (including YGTC and others) training could effectively improve sympathetic-vagal balance through measured parameters of heart rate variability as valid and reliable marker of ADHD [30].

Recently, YGTC has attracted increasing attention from researchers to investigate the beneficial effects of mindful exercises on health and behavioral outcomes of ADHD [31–34]. The increasing number of intervention studies on this topic have driven researchers to conduct reviews [35–37]. Notably, they are either narrative reviews [26,35] or meta-analysis that included Yoga exercise alone [37]. Furthermore, their literature search solely focused on English databases. Thus, an updated review that includes the two most widely practiced mindful exercise (YGTC) and both English and Chinese databases, with quantitative analysis, is needed. This systematic review with meta-analysis is to critically investigate the effects of YGTC on health and behavioral outcomes in children and adolescents with ADHD.

2 Methods

2.1 Search Strategy

Chinese and English electronic databases (PubMed, Web of Science, Scope, China National Knowledge Infrastructure and Wanfang) were searched for potential publications on 25 July, 2020. The keywords used for the search were as follows: (1) “Tai Chi” OR “Tai Chi Chuan” OR “Qigong” OR “Yoga” OR “Mind-body” AND (2) “ADHD” OR “Attention deficit hyperactivity disorder” OR “Deficit-Hyperactivity Disorders” OR “Attention Deficit Disorder”. A hand search was also completed to retrieve relevant articles based on the bibliographies of the included studies.

2.2 Inclusion and Exclusion Criteria

The included studies should meet the following criteria: (i) Participants were children and adolescents diagnosed with ADHD. (ii) The intervention was mind-body exercises (Tai Chi or Yoga) in treating ADHD. (iii) Study design was a randomized controlled trial (RCT) or non-RCT. (iv) The control group was given routine exercises or waitlist other than mind-body exercises. (v) Outcomes reflected the characteristics of ADHD (i.e., ADHD symptoms, hyperactivity, attention, or social problems).

Exclusion criteria were that: (i) Study was published in non-English or non-Chinese language. (ii) Participants were not diagnosed with ADHD. (iii) Effect size (ES) could not be calculated because of the insufficient information. (iv) Publications, such as case-study, observational studies, or review articles.

2.3 Study Selection, Data Extraction and Quality Assessment

Following the study selection, the same two authors extracted the data from each of the included studies using a predetermined data collection form. Any disagreements on study selection and data abstraction were resolved by the third reviewer. The following information was extracted: author and year of publication, study design, participants' characteristics, intervention protocol, measurements and safety.

According to the Physiotherapy Evidence Database (PEDro) scale [38], the quality of included studies were evaluated. This assessment tool includes 11 items: Eligibility criteria, random allocation, concealed allocation, similar measures between groups at baseline, instructor blinding, assessor blinding, participant blinding, less than 15% dropout rate, intention-to-treat analysis, statistical comparison between groups, and at least one set of outcomes estimated. If the study met each evaluation requirement, one point was marked in corresponding item. The study quality was classified as excellent (9–10 points), good (6–8 points), fair (4–5 points) and poor (less than 4 points).

2.4 Statistical Analysis

All statistical analyses were conducted using Comprehensive Meta-Analysis Software version 2.2, and a significance level of 0.05 was set. The direction was set as positive, representing that the intervention effect was favorable to the mindful exercises. Effect size (ES) was expressed using standardized mean difference (SMD) with 95% confidence intervals (CI). Of which, the SMD was calculated by subtracting the measure of experimental group from control group. All the positive SMDs mean that the mindful-exercise can produce greater beneficial effects than control group on different outcomes or vice versa. If a standard deviation (SD) was not reported in the original studies, the *t*-value and *p*-value were used to calculate the ES. The overall estimates were computed using a random-effects model. The ESs were commonly categorized as: small (0.2–0.49), moderate (0.50–0.79), and large (≥0.8) [2]. Heterogeneity among included studies was assessed by the I2 test, which was considered as low, moderate and high heterogeneity along with cut-off points 25%, 50% and 75%, respectively [39]. We did not perform moderator analysis and meta-regression because of the insufficient number of included studies.

3 Results

3.1 Search Results

The search and selection process are presented in Fig. 1, with 1422 records initially identified. After the removal of duplicates (n = 158), 1264 records were screened by reading the titles and abstracts. Then 19 full-texts articles were used for detailed review. Finally, seven eligible studies [40–46] were included in this meta-analysis.

3.2 Characteristics of Included Studies

Characteristics of the seven studies [40–46] from four countries are summarized in Tab. 1. Years of publication ranged from 2004 to 2018. A total of 249 participants (106 males) were diagnosed with

ADHD using different assessment tools (e.g., Conner's rating scale, Diagnostic and Statistical Manual of Mental Disorder-IV), and ranged in age from 3 to 13 years. All participants were given mindful exercises (Tai Chi or Yoga) by a qualified instructor. Of which three studies [41–43] reported the use of additional medication to control ADHD. A variety of intervention protocols were used (30–60 min each session, 1–3 times weekly for 6–20 weeks). Control groups were given no intervention, routine lifestyle, waitlist or other activities (i.e., cooperative games). All studies showed no adverse events following mindful exercises. The main measurements were evaluated through parents and teachers' report [40,43–45], and objectively computerized test [41,42,46]. Outcomes including ADHD overall symptoms [40,41], social problems [43–45], hyperactivity/impulsivity [41,43–45], and attention [41,42,46] were evaluated through parents and teachers' reports and objectively computerized tests.

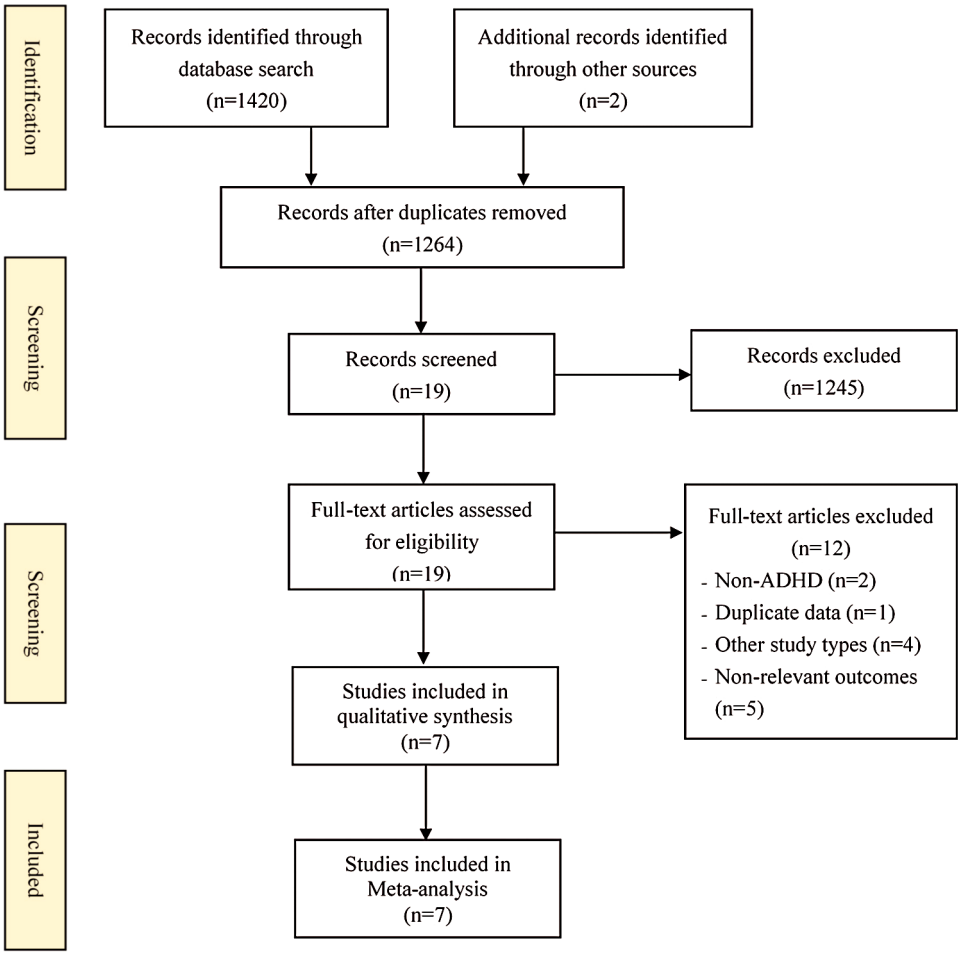

Figure 1: Process of eligible study selection

3.3 Quality Assessments

Methodological quality of included studies is presented in Tab. 2. All the included studies were with fair quality (4–5 points), except one had good quality (6 points) [41]. Two studies were not RCTs [44,45]. In addition, there were lack of concealed allocation, subject, instructor and assessor blinding, and intention-to-interest analysis in all the studies.

Table 1: Characteristics of randomized controlled trials in the meta-analysis

Study		Participants				Intervention protocol			Measurement	Safety
First author	Design (country)	Diagnosis (assessor)	N (male)	Mean Age/ age range	Medication Intake	Mindful Exercise (qualified instructor)	Control	Duration	Outcome (instrument); informant	Adverse effect
Abadi et al. [40]	NRS (Iran)	DSM-IV, (psychologist)	40 (NR)	10.1 years	NR	2 × 45 min/ week, Yoga (yes)	No intervention	8 weeks	ADHD overall symptoms (CSI-4), Parents and teachers	No
Cohen et al. [41]	RCT (USA)	DSM-IV (teachers or parents)	23 (15)	3 to 5 years	Only 1 child Medication intake	2 × 30 min/ week, Yoga (yes) plus Daily home practice	Waitlist	6 weeks	ADHD overall symptom (SDQ), Hyperactivity/impulsivity (subscales of DSM-IV), Parents/ teachers; Attention (KiTap), computerized test	No
Chou et al. [42]	NRS (China)	NR (psychiatric physicians and pediatricians)	50 (38)	10.5 years	22 of children Medication intake	2 × 40 min/ week, Yoga (yes)	No intervention	8 weeks	Attention (Visual Pursuit Test) Discrimination ability (Determination Test); Objectively Computerized Test	No
Jensen et al. [43]	RCT (Austria)	DSM-IV (pediatrician)	19 (19)	8 to13 years	Dexamphetamine, methylphenidate	1 × 60 min/ week, yoga (yes) plus Daily home practice	Cooperative games/ activities	20 weeks	Social problem, hyperactivity/ impulsivity; Parents and teachers	No
Wen [44]	RCT (China)	Conners Rating Scale (parents and teachers)	30 (18)	10.06 years	NR	3 × 45 min/ week Tai Chi (yes)	Waitlist	12 weeks	Hyperactivity/impulsivity, social problems (Children Behavior Checklist); Parents and teachers	No
Chen et al. [45]	RCT (China)	Conners Rating Scale (parents)	36 (17)	8 to 9 years	NR	3 × 60 min/ week Tai Chi (yes)	Routine lifestyle	16 weeks	Hyperactivity/impulsivity, social problems, (Children Behavior Checklist); parents	No
Rezaei et al. [46]	RCT (Iran)	Conners Rating Scale (parents)	21 (NR)	7 to11 years	NR	3 × 45 min/ week Yoga (yes)	Neurofeedback; No intervention	8 weeks	Attention (CPT); computerized test	No

Notes: ADHD = attention deficit/hyperactivity disorder; CPRS-R = The Conner's Teacher Rating Scale-Revised; CPT = Continue performance test; CSI-4 = The Child Symptom Inventory; DSM-IV = Diagnostic and Statistical Manual of Mental Disorder-IV; N = number of participants; NR = not reported; RS-4 = Rating scale-IV; NRS = Non-randomized controlled study; RCT = Randomized controlled trial; SDQ = Strengths and Difficulties Questionnaire.

Table 2: Methodological quality of the included studies (PEDro analysis)

Study	Score	Methodological quality	PEDro item number										
			1	2	3	4	5	6	7	8	9	10	11
Abadi [40]	4	Fair	✓			✓				✓		✓	✓
Cohen et al. [41]	6	Good	✓	✓		✓				✓	✓	✓	✓
Chou et al. [42]	4	Fair	✓			✓				✓		✓	✓
Jensen et al. [43]	5	Fair	✓	✓		✓				✓		✓	✓
Wen [44]	5	Fair	✓	✓		✓				✓		✓	✓
Chen et al. [45]	5	Fair	✓	✓		✓				✓		✓	✓
Rezaei et al. [46]	5	Fair	✓	✓		✓				✓		✓	✓

Studies were classified as having excellent (9–10), good (6–8), fair (4–5) or poor (<4). ✓, present. The PEDro scale criteria are (1) eligibility criteria; (2) random allocation; (3) concealed allocation; (4) similarity at baseline on key measures; (5) subject blinding; (6) therapist blinding; (7) assessor blinding; (8) less than 15% dropout rate; (9) intention-to-treat analysis; (10) between-group statistical comparison for at least 1 key outcome; and (11) point estimates and measures of variability provided for at least 1 key outcome.

3.4 Meta-Analysis Results

There were four outcomes related to ADHD characteristics: ADHD overall symptoms (n = 2, Fig. 2), social problems (n = 3, Fig. 3), hyperactivity/impulsivity (n = 4, Fig. 4), and attention (n = 2, Fig. 5). As shown in Tab. 3, the pooled results showed that mindful exercises had significantly effects on ADHD overall symptoms (SMD = 0.82, 95% CI 0.02 to 1.62, p = 0.04, I2 = 42%), social problems (SMD = 0.57, 95% CI 0.12 to 1.02, p = 0.01, I2 = 0%), hyperactivity/impulsive (SMD = 0.93, 95% CI 0.32 to 1.53, p < 0.01, I2 = 51%), and attention (SMD = 0.93, 95% CI 0.39 to 1.48, p < 0.01, I2 = 0%).

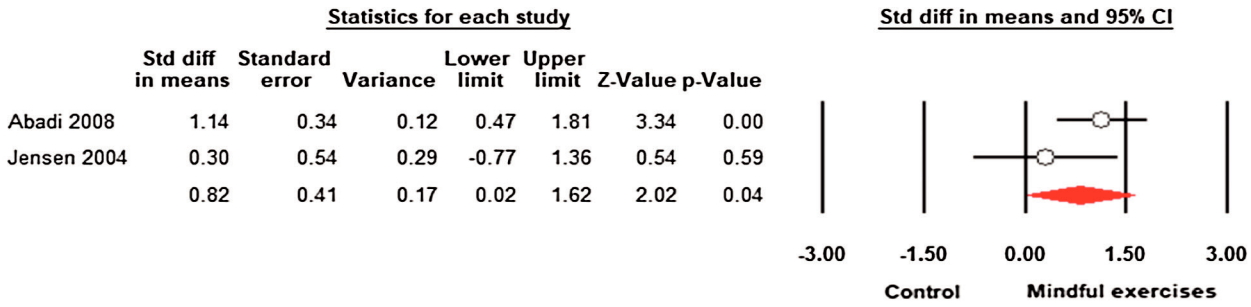

Figure 2: Effects of mindful exercises on ADHD symptoms

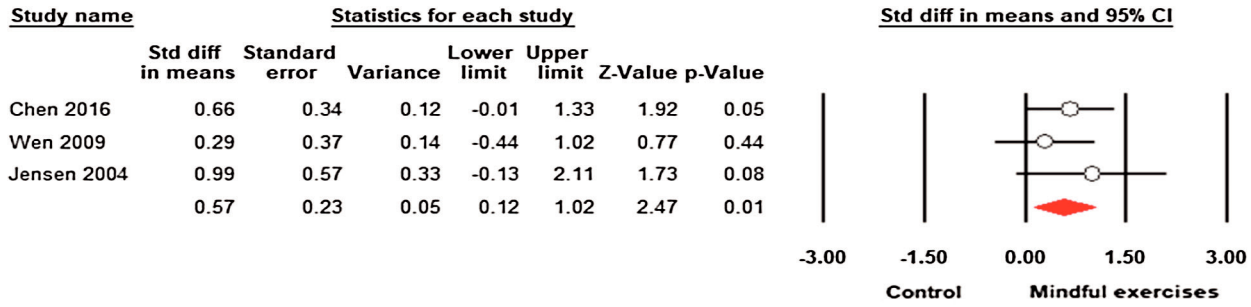

Figure 3: Effects of mindful exercises on social problems

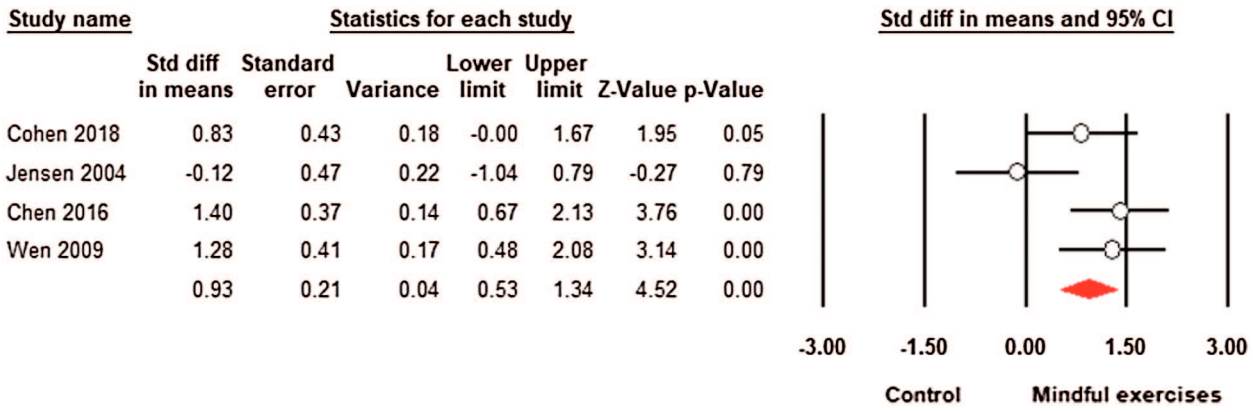

Figure 4: Effects of mindful exercises on hyperactivity/impulsivity

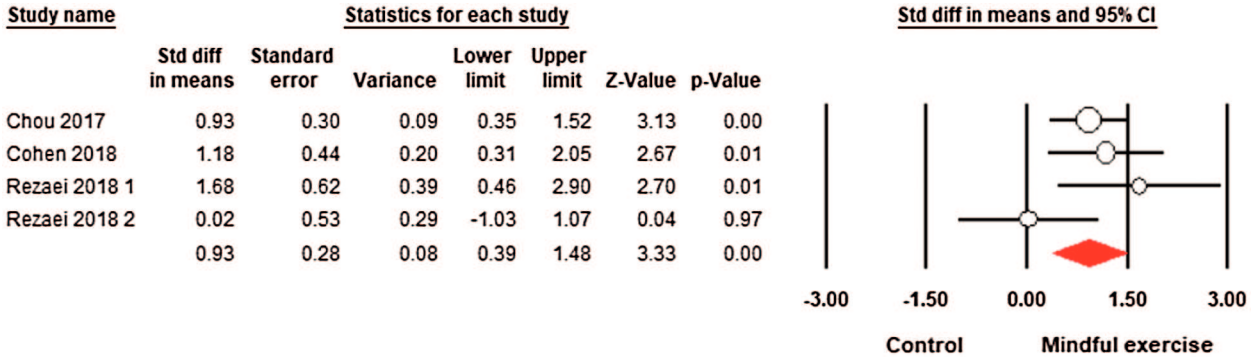

Figure 5: Effects of mindful exercises on attention

Table 3: Synthesized results for the effects of mindful exercises *vs.* control intervention

Outcomes	Number of trials	*SMD*	95% CI	*p*-value	I^2 %	Between-group homogeneity		
						Q-value	df(*Q*)	*p*-value
Overall ADHD symptoms	2	0.82	0. 02 to 1.62	0.04	42%	1.73	1	0.19
Social problems	3	0.57	0.12 to 1.02	0.01	0%	1.18	2	0.56
Hyperactivity/impulsive	4	0.93	0.32 to 1.53	0.00	51%	6.16	3	0.10
Attention	4	0.93	0.39 to 1.48	0.00	36%	4.66	3	0.20

Note: SMD = standardized mean difference.

4 Discussion

To the best of our knowledge, it is the first meta-analytic review investigating the effects of the two most widely practiced mindful exercises (YGTC) on children and adolescents with ADHD. In this review, as compared to control groups, YGTC interventions may potentially improve core symptoms of children and adolescents with ADHD, with moderate to large effect sizes. Our review findings are further discussed below.

4.1 Mindful Exercises for Attention

Attention deficit is one of core symptoms of ADHD [47]. Such mind wondering of children and adolescents with ADHD reflect insufficient efforts in keeping or returning their attention to sensations and

goal-directed actions [48,49]. Inattention symptoms have impaired on-task performance, which directly led to academic underachievement [50]. The present review results indicated that, as compared to control conditions (no intervention and waitlist), YGTC had a positive effect on improving attention ability of children and adolescents with ADHD. Furthermore, magnitude of the accumulated intervention effect was large (SMD = 1.01). Such significantly improved attention ability may be attributed to features of YGTC training. For example, practice of YGTC emphasizes process-centered principle (meditative mind) and muscular activity coordinated with mental focus on muscle and movement sense (proprioceptive and kinesthetic body awareness) [51]. It may prevent children and adolescents with ADHD from external distractions that certainly pull their attention away from on-task performance [52–54]. When looking into the included individual studies, we firstly found that an 8-week mindful exercise intervention (2 sessions/week × 40-minute/session) has started to trigger positive effects on attention [42]. Secondly, instructor-led training plus daily home practice is more effective in improving attention [42]. It may suggest that total training time is associated with magnitude of YGTC training effects. Future studies can further investigate dose-response effects of mindful exercise on this outcome.

4.2 Mindful Exercises for Hyperactivity/Impulsivity and Social Problem

Hyperactivity and impulsivity are also two of the ADHD core symptoms [55], which cause a variety of issues including impaired social functioning [56], strained parent-children relationship [57], and academic difficulties [58]. Early intervention plays a significant role in alleviating and preventing these symptoms so that they would not persist into adulthood. In the present study, as compared to control groups, YGTC training effectively reduced hyperactivity/impulsivity of children and adolescents with ADHD (SMD = 0.93). Notably, when taking a closer look at the effect of each individual study on hyperactivity/impulsivity, only one study by Jensen et al. [43] indicated non-significance. This insignificant finding may be attributed to the use of active control (cooperative games/activities involved multiple skills such talking and listening, turn-taking, sharing equipment, and talk time). These rule-oriented tasks are similar to school-based behavioral modification, which may also contribute to the reduction of hyperactive/impulsive symptoms. When these core symptoms improved, moderate to large positive effects of YGTC intervention on participants' social problems and overall ADHD symptoms were subsequently observed.

4.3 Limitations

Despite our meta-analytic review synthesized the efficacy of using YGTC training on ADHD related symptoms among children and adolescents with ADHD and identified some research gaps for future research, a few limitations need to be acknowledged. Although a meta-analysis can be conducted with as low as two studies, only six studies were included in this review, highlighting the pressing need to conduct similar and high-quality trials. Moreover, our limited our literature search on electronic English and Chinese databases, potential publications that are eligible to our inclusion criteria may have been excluded.

4.4 Conclusions

Overall, YGTC training is a safe training approach for children and adolescents with ADHD. However, there is limited evidence supporting their training effectiveness on ADHD related symptoms especially for overall ADHD symptoms and attention. More trails with high methodological quality are needed in future to provide additional evidence on whether YGTC is an effective alternative treatment approach to medications.

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Author Contributions: Conceptualization; methodology; formal analysis, EFZ., LP., Y.Y; writing—original draft preparation; writing—review and editing.

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