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A meta-analytic investigation of the impact of mindfulness-based interventions on ADHD symptoms

Jiaming Xue, BS[a], Yun Zhang, BS[a], Ying Huang, MD[b,*]

Abstract

Background: Mindfulness-based interventions (MBIs) have been reported to be efficacious in treating attention deficit hyperactivity disorder (ADHD). However, the value of the control effect of MBIs on ADHD core symptoms remains controversial. To clarify the literature on the control effect of MBIs on the symptoms of ADHD and guide future researches, an effect-size analysis was conducted.

Methods: A systematic search in PubMed, Embase, Web of Science, Medline, Cochrane Library, China National Knowledge Infrastructure, and Wangfang Data databases was performed up to January 11, 2019. The overall effect size of MBIs on ADHD core symptoms (ie, inattention and hyperactivity/impulsivity) was recorded by the metric of Hedges' *g* with 95% confidence interval, *Z*-value, and *P*-value.

Results: Eleven eligible studies featuring 682 participants were included in the meta-analysis. The overall results indicated that MBIs had large effects on inattention (Hedges' $g = -0.825$) and hyperactivity/impulsivity (Hedges' $g = -0.676$) relative to the control group. Results from subgroup analyses between self- and observer rating on ADHD symptoms revealed that the effect of MBIs both remained in a large range and self-rated ADHD core symptom had a greater impact on heterogeneity across the studies. Meta-regression found that the overall effect might be moderated by participant age group and control condition.

Conclusion: The present meta-analysis suggested that MBIs had large effects in reducing ADHD core symptoms in comparison with the control group. Future researches are needed to assess follow-up effects of MBIs on ADHD core symptoms and explore the correlation between the individual level of mindfulness and reduction of ADHD symptoms.

Abbreviations: ADHD = attention deficit hyperactivity disorder, MAP = mindful awareness practices, MBCT = mindfulness-based cognitive therapy, MBIs = mindfulness-based interventions, SE = standard error, TAU = treatment as usual, WT = wait-list.

Keywords: ADHD, meta-analysis, mindfulness, mindfulness-based therapies

1. Introduction

Characterized by the core symptoms of excessive motor activity, difficulty in maintaining attention and impulsivity, attention deficit hyperactivity disorder (ADHD) is a childhood-onset neurodevelopmental disorder.[1] The pooled estimated prevalence of ADHD is around 5%.[2] Although in the past it was suggested that most children with ADHD would recover in adulthood, now powerful evidence has shown that impairing symptoms of ADHD persist into adulthood in two-thirds of the cases.[3] The disorder affects about 2.5% of the adult population,[4] which is closely related to the impairment in social interactions,[5] academic achievement,[6] and work productivity.[7] Therefore, the need to treat ADHD is evidenced by the significant influence that the disorder has on the different areas of patients' life.

The recommended therapy for ADHD includes pharmacologic and non-pharmacologic interventions. Pharmaceuticals for ADHD include psychostimulants (ie, methylphenidate and amphetamines), are recommended as the first pharmacological choice in some guidelines.[8] However, drug therapy has limitations, such as adverse effects and a high dropout rate,[9] and many patients showed partial or even no responses to the treatment.[10] Those nonresponders might continue to put up with the impairing symptoms. An accelerating number of studies over the past 2 decades have investigated the efficacy of nonpharmacologic interventions for patients with ADHD, which involve training patients in cognitive and behavioral skills to address symptoms.[11]

Therefore, different psychosocial approaches have been designed for the therapy of ADHD, including mindfulness-based interventions (MBIs) which emphasize an observant and nonreactive attitude toward one's thoughts, emotions, and body state.[12] MBIs are considered as a type of cognitive training which could improve attention, self-regulation abilities, and quality of life for patients with ADHD.[13]

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JX and YZ contributed equally to this article.

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Previously meta-analytic review found that MBIs were efficacious in treating ADHD.[11] However, many of the studies included in that meta-analysis did not provide information on control groups, which were instructed treatment as usual (TAU), wait-list (WT), active control or offered the same intervention at the end of the study. Likewise, several recently published significant studies have not been included in that meta-analysis.[11]

A number of studies have examined the effects of MBIs on ADHD symptoms and conclude that MBIs might be a valuable treatment option alongside TAU or WT for ADHD,[14–20] although the magnitudes of the reported effects are heterogeneous. To date, no other new meta-analytical review of the effects of MBIs on patients with ADHD has been performed.

To provide researchers and clinicians with a detailed and useful quantitative summary of the evidence for MBIs for ADHD, we conducted a meta-analysis of treatment studies. Our analysis was guided by the following goals:

(1) evaluate the magnitude of the control effects of MBIs for ADHD symptoms,
(2) examine whether effects across studies are indeed heterogeneous, and
(3) explore the influence factors of control effects, such as self- and observer rating.

2. Materials and methods

2.1. Literature search

Studies of MBIs for ADHD patients are collected by searching the following databases: PubMed, Embase, Web of Science, Medline, Cochrane Library, China National Knowledge Infrastructure, and Wangfang Data. The search terms represented by abbreviations and full text were "mindful" or "mindfulness" in combination with "ADHD," "attention deficit-hyperactivity disorder," "attention deficit disorder," "hyperkinetic syndrome," or "brain dysfunction, minimal." We repeated the search 3 times during the process of the meta-analysis to identify the newly published studies, and the last search was performed on January 11, 2019. In addition, reference lists of related reviews and retrieved articles were checked to determine whether any studies were not identified in the aforementioned search.

2.2. Inclusion and exclusion criteria

The inclusion criteria for studies in the meta-analysis were as follows:

(1) the intervention based on mindfulness either with or without guidance,
(2) an inactive or active control condition included,
(3) participants clinically diagnosed as ADHD according to any diagnostic criterion, such as Diagnostic and Statistical Manual of Mental Disorders Fifth Edition,[1] and
(4) valid outcome measurements used to examine the effectiveness of MBIs on ADHD symptoms.

The exclusion criteria were:

(1) the intervention combined mindfulness-based exercises with other psychoeducational programs making it difficult to evaluate the effectiveness of mindfulness on ADHD core symptoms,
(2) the article did not provide sufficient information for the calculation of effect size between the experimental and control groups, and
(3) articles involved duplicate or overlapping studies.

This procedure was carried out by 2 independent reviewers. If they had disagreements, the third reviewer was consulted after discussions without reaching any consensus.

2.3. Data extraction and quality assessment

Data extraction was independently conducted by 2 reviewers to ensure the accuracy of the data reported in the articles. In each eligible study, the following information was extracted:

(1) the study characteristics (eg, study source, design, control condition, follow-up timing),
(2) the participants' characteristics (eg, mean age or range, gender distribution, ADHD subtypes),
(3) the treatment characteristics (eg, type of MBIs, duration in weeks), and
(4) outcome measures for ADHD symptoms and mindfulness.

Meanwhile, the quality of the included articles was examined using the Jadad scale with a total score ranging from 0 to 7,[21] and the Cochrane Risk of Bias Tool. Articles rated 4 to 7 points by the Jadad scale were regarded as high quality. The Cochrane Risk of Bias Tool consists of random sequence generation, allocation concealment, performance and detection bias, incomplete outcome data, selective reporting, and other bias.[22] According to this assessment, each eligible article was marked unclear, low or high bias.

2.4. Calculation of effect sizes

The primary analysis was to examine the overall effect size of MBIs separately on ADHD core symptomatology (ie, inattention and hyperactivity/impulsivity). The overall effect size was recorded by the metric of Hedges' g to correct the small sample bias.[23] We used Comprehensive Meta-Analysis software version 3 to convert the reported data,[24] such as Cohen d, means of pre- and post-treatment and standard deviations for the experiment and control groups, into Hedges' g. Since the pre- and post-measures within the group were not independent and the correlation between them was not often mentioned in the articles, we use 0.7 as a conservative estimate.[25] If participants in the same group were evaluated by different informants (eg, both self- and teacher rating), the mean of the outcomes was used to contribute 1 single effect size to the main analysis. Subgroup analyses and meta-regression were conducted to determine if the variable (eg, informant, age) across the articles might have contributed to heterogeneity within the analyses. We performed subgroup analyses based on the type of informant for the examination of the difference in effect size. The mixed effects model was applied in meta-regression to determine whether the variables differ across the studies. The variables were published year, study quality, the age of participants (ie, child or adult), control condition (ie, TAU, WT, or active control), type of MBIs (ie, mindfulness-based cognitive therapy [MBCT], mindful awareness practices [MAP], or others), and the duration of MBIs (in weeks). According to Lipsey and Wilson,[26] an effect size from 0.00 to 0.32 was considered as small, 0.33 to 0.55 as moderate, and 0.56 to 1.20 as large.

2.5. Statistical analysis

The meta-analysis was performed by pooling the data in Comprehensive Meta-Analysis software version 3 to calculate Hedges' *g* with 95% confidence interval, standard error (SE), *Z*-value, and *P*-value and present a forest plot for the primary analysis. Considering the variation (eg, participants characteristics, type of MBIs) in the articles that met the inclusion criteria, we assume that the true effect would not stay stable across the articles. Therefore, a random effects model was utilized in the meta-analysis. The I^2 and Chi-square-based *Q* test were used for the assessment of the overall heterogeneity between articles. The *Q*-statistic suggests if the presence of significant heterogeneity. The I^2 describes the proportion of heterogeneity across the articles.[27] And 25%, 50%, and 75% of I^2 mean low, moderate and high heterogeneity, respectively.[28] Sensitivity analysis was conducted by excluding eligible studies sequentially to determine the effect of every single eligible study on final results. The evaluation of publication bias was carried out using a funnel plot, a classic fail-safe *N* test, and Duval and Tweedle's trim and fill method. The asymmetric distribution in a funnel plot indicates the presence of the potential bias.[29] The calculation of Rosenthal's fail-safe N produces the estimated number of unpublished studies needed for reducing the effect size below significance.[30,31] Duval and Tweedle's trim and fill method was adopted to impute the value of missing studies and generate an adjusted effect size on the basis of the impact of these missing studies.[32]

2.6. Ethical approval

This meta-analysis does not require ethical approval or patient consent because the data used in the meta-analysis were extracted from previously published studies which had declared ethical approvals and no original clinical raw data was utilized. This meta-analysis was performed in accordance with PRISMA guidelines.

3. Results

As showed in Figure 1, according to the search strategy, 379 articles in total were identified and another 3 studies were collected through manual search. A total of 304 articles were excluded after removing duplications. After scanning the title and abstracts, 35 articles were eliminated because they were not related to the purpose of the meta-analysis. A total of 31 articles were excluded for various reasons by further full-view screening. Thence, 12 eligible articles met the inclusion criteria. However, 1 of these 12 articles was excluded for not providing sufficient statistical results to calculate the effect size.

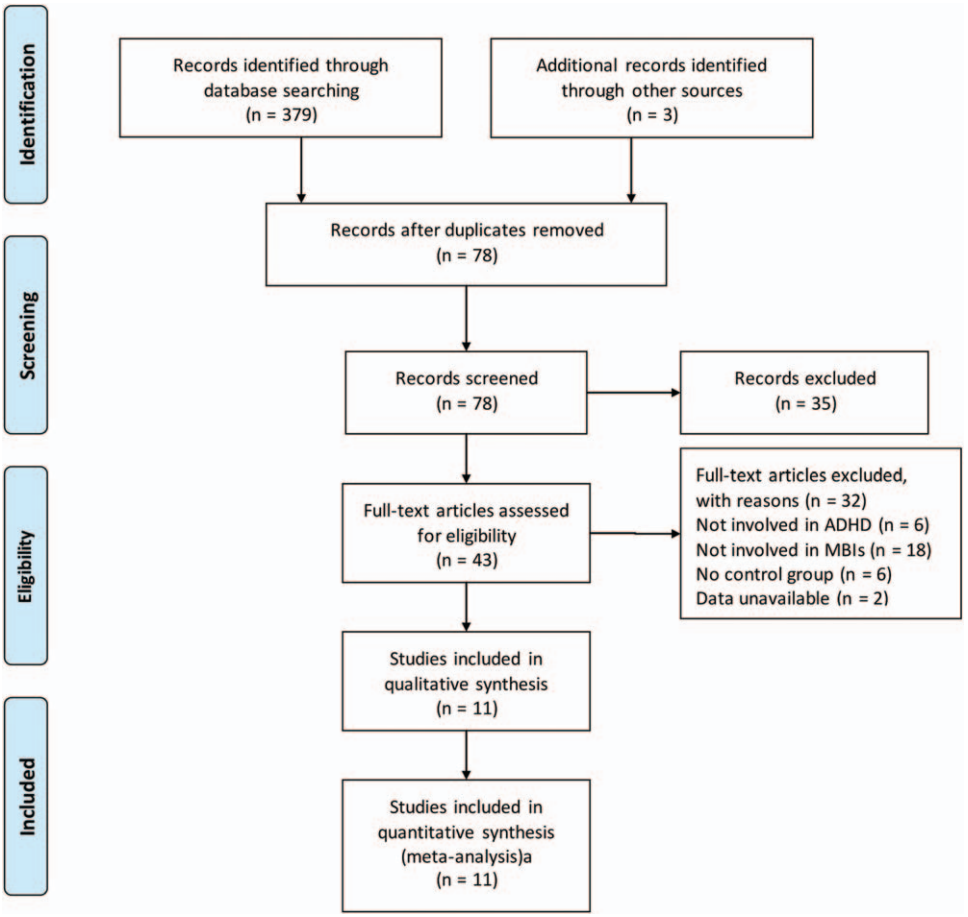

Figure 1. Flow diagram of literature selection for meta-analysis.

Table 1

Characteristics of studies included in the analysis.

Study (yr, country)	Age	ADHD subtype (%)	Male (%)	Experimental group			Control group			Follow-up time	Outcome measurement			Quality score
				N	Age, mean (SD), or range	Intervention	N	Age, mean (SD), or range	Intervention		ADHD symptoms	Mindfulness	Informant	
Bachmann et al (2018, Germany)	Adult	C: 80.9; IN: 19.1	45.0	21	40 (10.58)	MAP (8 wk)	19	40.26 (13.81)	PE	None	CAARS-INV: SV; CAARS-S:SV	None	Observer and self	6
Behbahani et al (2018, Iran)	Child	C: 100	66.1	30	8.65 (1.64)	Mindful parenting training (8 wk)	26	8.73 (1.65)	TAU	2 mo	SNAP-IV	None	Observer	5
Bueno et al (2015, Israel)	Adult	NR	53.5	21	31.2 (7.5)	MAP (8 wk)	22	31.7 (7.80)	WT	None	ASRS	None	Self	3
Edel et al (2014, Germany)	Adult	C: 30.8; IN: 69.2	60.4	39	33.8 (10.1)	MBTG (12 wk)	52	36.7 (10.10)	STG	None	WRI;I-SR;B-SR; Q-OR;D-OR	MAAS	Observer and self	3
Fleming et al (2015, US)	Adult	C: 15.2; IN: 84.9	57.6	17	21.2 (1.67)	DBT (8 wk)	16	21.5 (1.12)	Skills handouts	3 mo	BAARS-IV	FFMQ	Self	4
Gu et al (2018, China)	Adult	C: 10.7; IN: 93.3	42.9	28	19-24	MBCT (6 wk)	26	19-24	WT	3 mo	CAARS-S:SV	MAAS	Self	6
Hoxhaj et al (2018, Germany)	Adult	C: 84.0; IN: 16.0	48.0	41	40.5 (9.48)	MAP (8 wk)	40	38.5 (11.83)	PE	8 mo	CAARS-INV:SV; CAARS-S:SV	FFMQ	Observer and self	7
Janssen et al (2018, the Netherlands)	Adult	C: 48.0; IN: 44.0; HI: 5.0; Unknown: 3.0	40.0	60	39.7 (11.1)	MBCT (8 wk)	60	39.0 (10.10)	TAU	6 mo	CAARS-INV:SV; CAARS-S:SV	FFMQ	Observer and self	6
Lo et al (2017, China)	Child	NR	12.0	50	6.24 (0.87)	FBMI (6 wk)	50	5.92 (0.70)	WT	None	SWAN	None	Observer	6
Mitchell et al (2013, US)	Adult	C: 30.6; IN: 69.4	40.0	11	40.5 (6.83)	MAP (8 wk)	9	36.22 (6.92)	WT	None	CAARS-INV:SV; CAARS-S:SV	None	Observer and self	4
Schoenberg et al (2014, the Netherlands)	Adult	NR	NR	24	18-65	MBCT (12 wk)	20	18-65	WT	None	CAARS-S:SV	KIMS	Observer	5

ADHD = attention deficit hyperactivity disorder, ASRS = adult ADHD self-report scale, BAARS-IV = Barkley adult ADHD rating scale-4th edition, C = combined subtype, CAARS-INV: SV = the investigator-rated screening version of the Conners' adult ADHD rating scale, CAARS-S: SV = Conners' adult ADHD rating scale-self-report: screening version, DBT = dialectical behavior therapy, FBMI = family-based mindfulness, FFMQ = five facet mindfulness questionnaire-short form, HI = hyperactive/impulsive subtype, IN = inattentive subtype, KIMS = Kentucky inventory of mindfulness, MAAS = mindful attention and awareness scale, MAP = mindful awareness practices, MBCT = mindfulness-based cognitive therapy, MBTG = mindfulness-based training group, NR = not report, OR = rating by others (Q = quantity, D = disturbance), PE = psychoeducation, SD = standard deviation, SNAP-IV = Swanson, Nolan, and Pelham parent and teacher rating scale, SR = self-rating (I = impairment, B = burden), STG = skills training group, SWAN = strengths and weaknesses of ADHD symptoms and normal behaviors rating scales, TAU = treatment as usual, WRI = Wender–Reimherr interview, WT = wait-list.

3.1. Characteristics of included studies and quality appraisal

As presented in Table 1,[14–20,33–36] 3 included studies were conducted in Germany, 2 each in the United States, the Netherlands and China, each 1 in Iran, and Israel, including 682 participants. Of all participants, 210 were children and 472 were adults. MBIs differ in duration, frequency, and components. A MAP program was applied in 4 studies.[17,19,33,34] An MBCT program was applied in 3 studies.[14,15,20] Two studies[16,18] involved mindful parenting programs. A mindfulness-based training group program was applied in 1 study.[36] The MBIs group received 8 weeks exercises in 7 studies,[14,16,17,19,33–35] 12 weeks in 2 studies[20,36] and 6 weeks in 2 studies.[15,18] The active control was conducted in 4 studies,[33–36] WT in 5 studies[15,17–20] and TAU in 2 studies.[14,16] The outcome results of ADHD core symptoms of inattention in comparison were reported in 11 studies and hyperactivity/impulsivity in 10 studies. Five studies[14,17,33,34,36] reported outcome results by both self- and observer ratings, and other studies reported only by self- or observer ratings for ADHA symptoms. In addition, a total of the quality appraisal scores of each eligible article shown in Table 1 ranged from 3 to 7. Eight of all included studies were of moderate qualities, 2 of low qualities and 1 of the high quality.

3.2. Effects on ADHD symptoms

Based on 11 studies, the combined effect size of the MBIs on inattention was $g = -0.825$ (95% CI = −1.161, −0.488, $Z = -4.805$, $P < .001$), suggesting that significant effect of MBIs on the reduction of inattention (Fig. 2). The assessment of overall heterogeneity across the articles indicated the nonignorable presence of heterogeneity ($Q = 42.10$, df = 10, $P < .001$). The I^2 with 76.24% suggested high heterogeneity as a result of the moderate variability across the articles. A large effect on hyperactivity/impulsivity was observed with $g = -0.676$ (95% CI = −0.975, −0.377, $Z = -4.433$, $P < .001$) as presented in Figure 3. The heterogeneity test results showed moderate heterogeneity within studies with $Q = 29.13$ (df = 9, $P = .001$) and $I^2 = 69.10\%$.

3.3. Subgroup analyses

In the subgroup analysis of self- and observer rating for inattention, the effect size for self-rating ($g = -0.809$, 95% CI = −1.258, −0.361, $Z = -3.537$, $P < .001$) was in large range and the effect size for observer rating ($g = -0.678$, 95% CI = −1.031, −0.325, $Z = -3.76$, $P < .001$) was in smaller range than self-rating (Fig. 4). In addition, the high heterogeneity was observed in self-rating ($Q = 36.47$, $P < .001$, $I^2 = 80.80\%$) and the moderate to high heterogeneity in observer rating ($Q = 26.05$, $P < .001$, $I^2 = 73.13\%$) for inattention. As for hyperactivity/impulsivity, the results demonstrated that the estimated effect size both remained in large range with $g = -0.680$ (95% CI = −1.092, −0.268, $Z = -3.234$, $P = .001$) for self-rating and $g = -0.546$ (95% CI = −0.835 −0.258, $Z = -3.711$, $P < .001$) for observer rating (Fig. 5). However, the higher heterogeneity within studies was found in self-rating ($Q = 24.81$, $P < .001$, $I^2 = 75.82\%$) than observer-rating ($Q = 18.17$, $P = .01$, $I^2 = 61.47\%$).

3.4. Meta-regression analyses

The meta-regression results showed that the overall effect size was significantly moderated by the control condition for MBIs on inattention ($\beta = -0.37$, SE = 0.12, $P < .001$) and hyperactivity/impulsivity ($\beta = -0.32$, SE = 0.14, $P = .01$), suggesting that the effect size was larger for the MBIs group when compared to WT or TAU conditions than active conditions. Likewise, we found that participants' age group had a moderating effect on overall effect size for inattention ($\beta = -0.30$, SE = 0.45, $P = .50$) and hyperactivity/impulsivity ($\beta = -0.3$, SE = 0.34, $P = .88$), but the results were of low statistical power. Meanwhile, there is no evidence that publish year, study quality, MBIs type, and treatment duration as confounding factors substantially contributed to heterogeneity

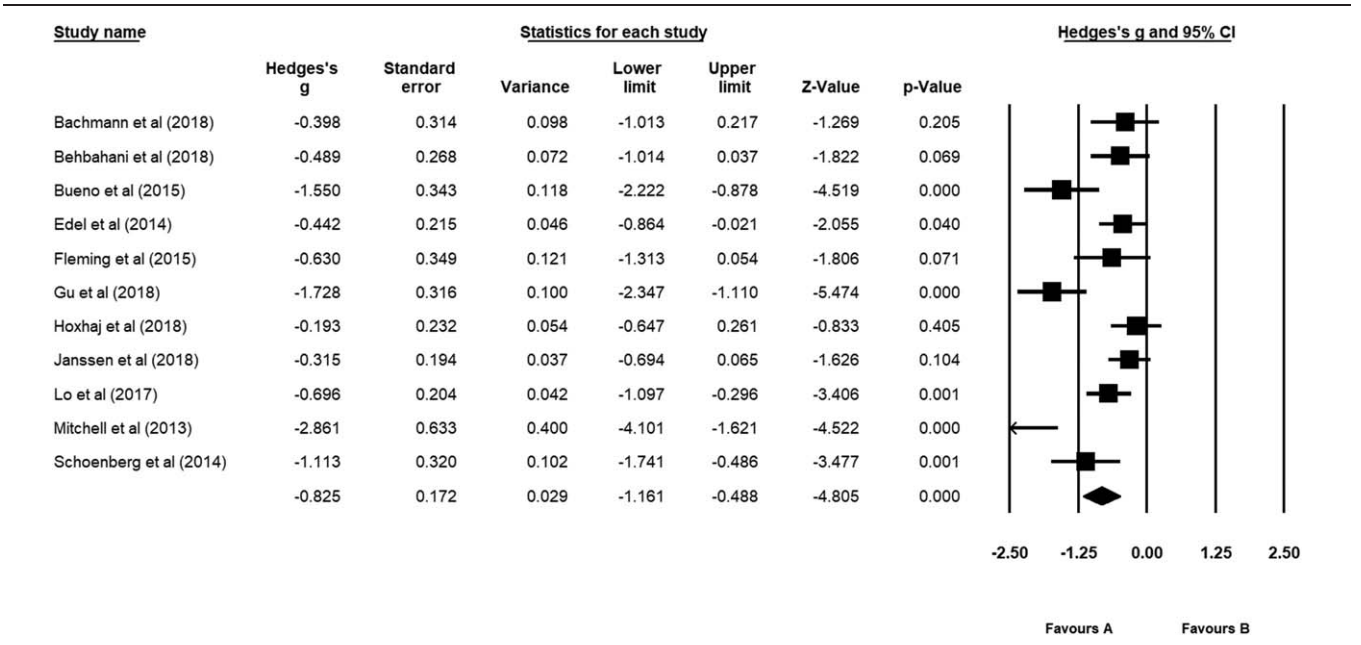

Figure 2. Primary analysis of inattention. CI = confidence interval.

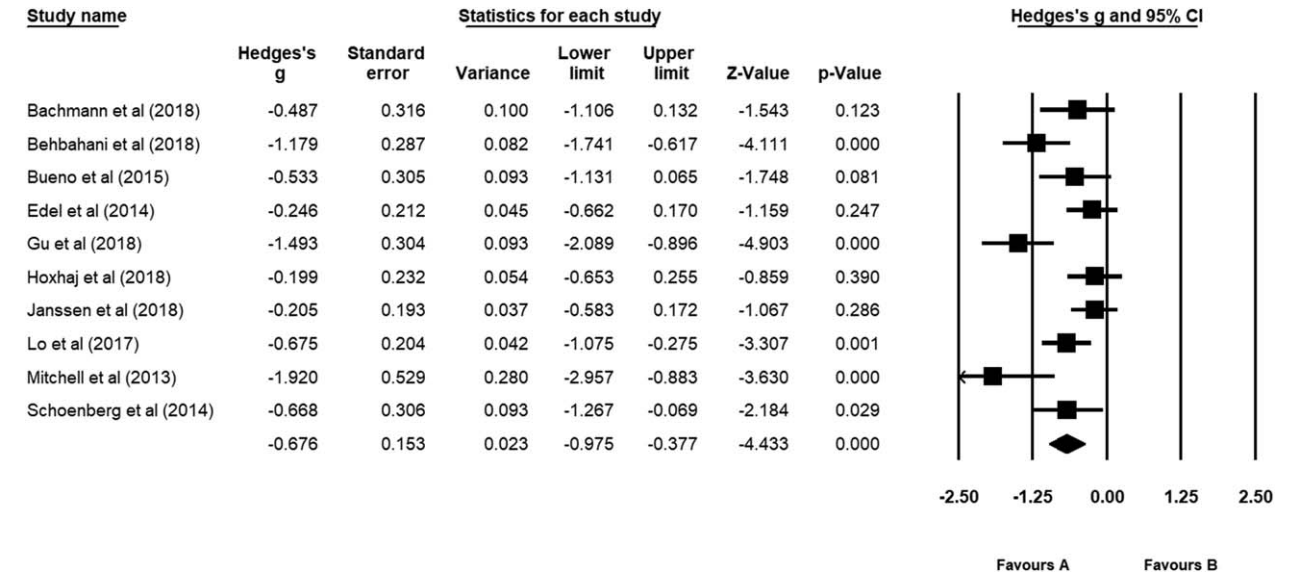

Figure 3. Primary analysis of hyperactivity/impulsivity. CI = confidence interval.

according to the meta-regression analyses (adjusted *P*-value is .02, .08, .28, and >.99 for inattention and >.99, .91, .59, .04 for hyperactivity/impulsivity, respectively), but the results for MBIs type and treatment duration were unpowered as well.

3.5. Publication bias and sensitivity analyses

The calculation of the classic fail-safe N showed the number of unpublished studies required for showing the nonsignificant effects for inattention (237) and hyperactivity/impulsivity (147) exceeded the recommended minimum of 65 (5 *k* + 10, where *k* is the number of studies in the meta-analysis).[25] There are no missing articles to the right mean using a random model according to the Duval and Tweedie's trim and fill for inattention and hyperactivity/impulsivity. Similarly, the Begg funnel plot showed the basically symmetric distribution (Figs. 6 and 7). Moreover, sensitivity analyses were performed by removing included articles sequentially to determine the impact of every single included study on the obtained results above. The corresponding Hedges' *g* of inattention and hyperactivity/impulsivity was not greatly altered during this procedure, indicating the stability of our meta-analysis.

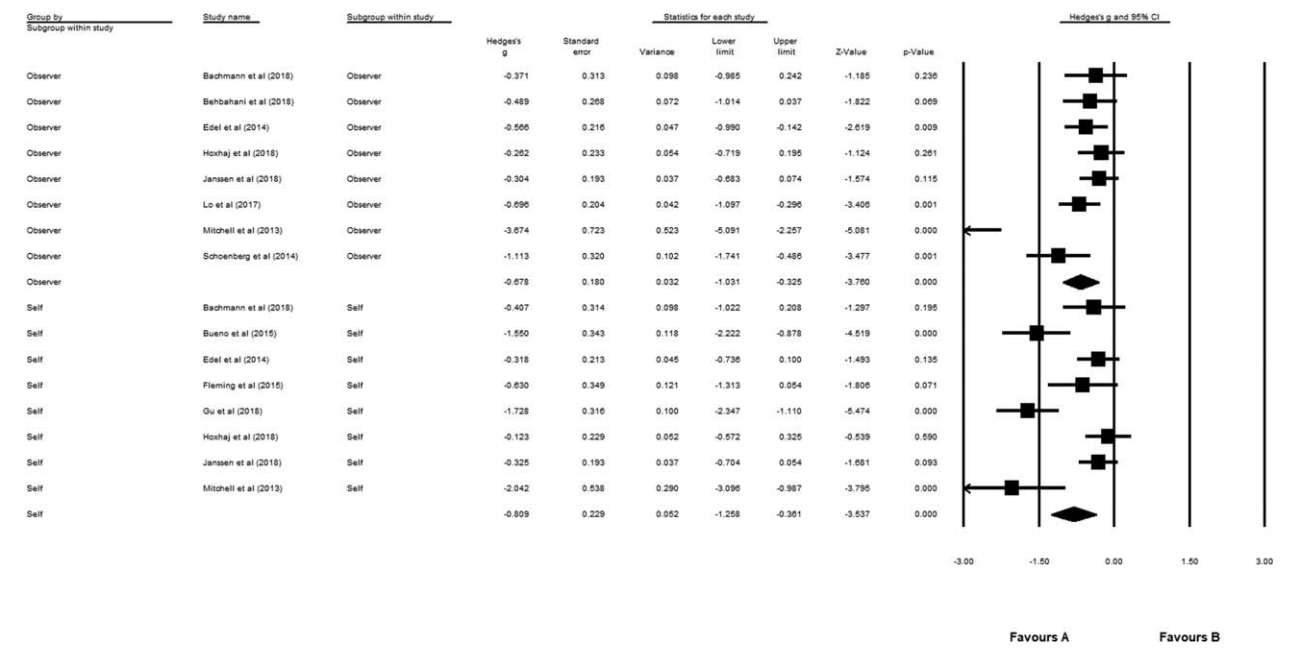

Figure 4. Subgroup analysis of inattention by informant report. CI = confidence interval.

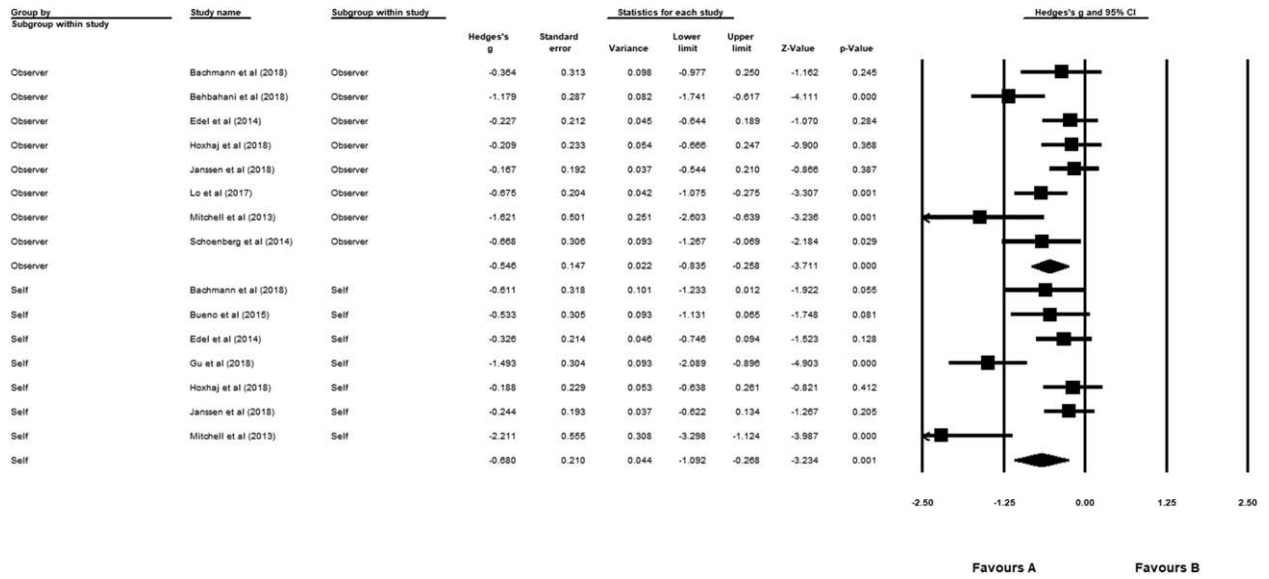

Figure 5. Subgroup analysis of hyperactivity or impulsivity/informant report. CI = confidence interval.

3.6. Effects on mindfulness

In all 11 included studies, there were merely 6 studies examined the effect of MBIs on mindfulness of participants compared to control conditions. The overall mean effect size was $g = -0.538$ (95% CI = −0.876, −0.201, $Z = -3.125$, $P = .002$), indicating a moderate to high range of effect on mindfulness of participants. High heterogeneity was found across the studies with $Q = 23.61$ ($P < .001$) and $I^2 = 78.83\%$.

4. Discussion

The main purpose of this meta-analysis was to estimate the overall effect size of MBIs on ADHD core symptoms (ie, inattention and hyperactivity/impulsivity) in comparison with control conditions. The previous meta-analysis merely evaluated the difference of ADHD core symptoms between pre- and postintervention within the group without including information of control groups.[11] When all studies were included, the primary results showed a large effect size for ADHD core symptoms, suggesting that MBIs could significantly reduce ADHD core symptoms. In addition, the effect of MBIs on inattention ($g = -0.825$) was larger than hyperactivity/impulsivity ($g = -0.676$). It seemed to be a result of mindfulness-based exercise, which more emphasized nonjudgemental attention of participants to one's occurring experience in the present moment to improve attentional regulation.[37] And the evidence of improvement of attentional regulation involving executive functioning processes as the potential mechanism of mindfulness-based treatment reducing ADHD core symptoms was provided in several studies.[38,39] Some studies proposed the enhancement of emotional regulation as one of the potential mechanisms as well.[38,40] Mindfulness-based exercise might exert an impact on

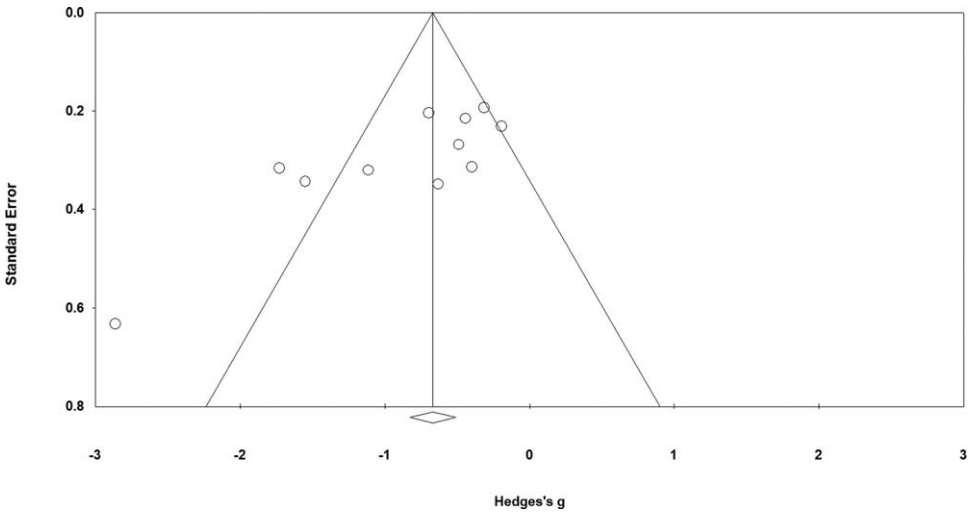

Figure 6. Publication bias in inattention studies.

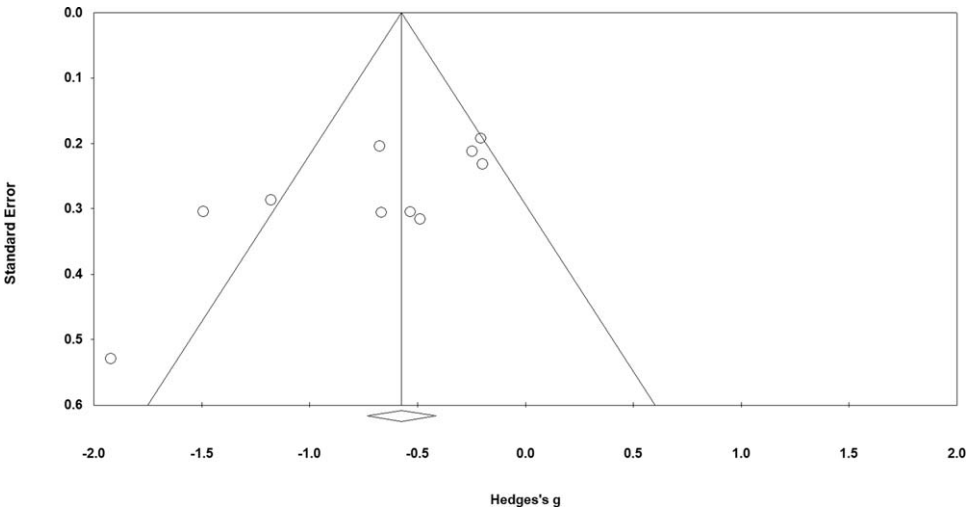

Figure 7. Publication bias in hyperactivity/impulsivity studies.

ADHD core symptoms through those potential mechanisms account for these domains frequently associated with ADHD core symptoms.[17]

Results from subgroup analyses between self- and observer rating for ADHD core symptoms revealed that the mean effect size still remained in a large range compared to control conditions, indicating the efficacy of MBIs on the reduction of ADHD symptoms irrespective of the informant. It seemed that MBIs were of great efficacy in individuals with ADHD.

However, we must interpret these results with cautions when taking the heterogeneity across the studies into account. The variables across the studies having substantial influence on heterogeneity were as follows:

(1) participant age group,
(2) control condition,
(3) publish year,
(4) study quality,
(5) type of MBIs,
(6) the duration of intervention, and
(7) type of informant.

Sensitivity analyses, subgroup analyses, and meta-regression were conducted to identify the causes of heterogeneity. First, sensitivity analyses showed that the similar effect size of MBIs on ADHD core symptoms was obtained after excluding each included studies sequentially. Second, according to subgroup analyses aforementioned, the type of informant contributed to the significant heterogeneity. Heterogeneity was both in high range in the self-rating group of inattention and hyperactivity/impulsivity according to the heterogeneity test while in moderate range in the observer rating group, indicating self-reported ADHD core symptoms had a greater impact on heterogeneity across the studies. Similar results were reported in the previous post-treatment meta-analyses.

Furthermore, meta-regression was performed to determine the possible confounding factors. The results mentioned above revealed that control conditions had a great impact on heterogeneity, which suggested the smaller effect on ADHD core symptoms when compared to active conditions than inactive conditions (ie, WT or TAU). The active control group helped to control the alternative interpretation of the possible effects of the intervention, which can be an explanation for the meta-regression results. We also found that the age of participants significantly affected the heterogeneity. One possible explanation for this could be that adults had a better understanding of their condition and more self-consciously involved in the treatment than children. Another possible explanation could be that the length of intervention, mindfulness techniques, homework, and the therapist characteristics might have different effects on different age of participants. Moreover, the notable finding from some studies that parenting stress plays an important part in the ADHD severity of the clinical symptoms of children.[16] Parents of children with ADHD may tend to pay more attention to children's behavioral problems, causing them to act in a punishing and impulsive way in which might directly increase the clinical symptoms of children with ADHD.[41] A growing amount of evidence that by improving parent-child interpersonal relationships and reducing overreaction to the children's behavioral problems, mindfulness parenting training could reduce parenting stress related to a decrease in ADHD symptoms.[41] In 2 included studies,[16,18] they both conducting the mindful parenting training on children and their parents reported similar results. Results of meta-regression also revealed that publishing year, study quality, and mindfulness-based treatment type and treatment duration did not substantially affect the heterogeneity.

In all 11 studies, only 6 studies examined the level of mindfulness of participants and we calculated the mean effect size in comparison with control conditions, which was in a moderate range. Due to the small size of the sample and high heterogeneity across the studies, it was difficult to determine the true effect on mindfulness and the association between the improvement of mindfulness and the reduction of ADHD symptoms. Some studies find out that the enhancement of the ability to describe and act with awareness, and nonjudge of inner experience through the mindfulness-based treatment is related to the reduction of ADHD core symptoms.[42–44] Moreover, by adopting an attitude of nonjudgment, the experience was regarded as neither positive nor negative, which helped to avoid falling into negative thought and behavior patterns according to

some studies.[33] However, more rigorous studies are still needed in the future to explore the correlation between the individual level of mindfulness and improvement of ADHD symptoms.

Only 6 studies of 11 included studies assessed ADHD core symptoms months after MBIs. The results showed that the gains were maintained for 2 to 8 months, but we must interpret these results cautiously because of the small size of the sample and high heterogeneity across the studies. In a chronic disorder like ADHD, it is important to evaluate the stability of improvements when examining the effectiveness of mindfulness-based treatment which aims at the long-term effect on reducing core symptoms of ADHD. Thus in the future investigation of the efficacy of mindfulness-based treatment on ADHD symptoms, evaluation of follow-up effects should be paid more attention.[45]

In order to make sure that the results are properly interpreted, the limitations should be taken into account. First of all, we failed to conduct further analysis to investigate other influence factors for the moderating effects on the overall effect size for insufficient original data. With the growing body of literature examining the effects of MBIs on ADHD, importance should be attached to report these potential confounding factors (eg, the gender of patients, the subtype of ADHD) for future investigations so that the correlation between these factors and effectiveness of mindfulness-based treatment can be examined. Then, there remained an unclear risk of bias across the studies. Inappropriate outcome measures, unblinded observers, inaccurate descriptions of dropouts (and their causes), and pseudo-random methods of allocation were the main sources of bias. The internal validity of findings can be improved by addressing larger samples, multicenter studies, details of the MBIs, the inclusion of a proper control group, double-blind observers, accurate descriptions of dropouts and the appropriate allocation/randomization process in future investigations. Finally, although ADHD is independent of another comorbidity, the effect of mindfulness-based treatment on symptoms of ADHD may be influenced by comorbid mood disorders. Without sufficient data, we were unable to evaluate the impact of comorbidity on the effect of the final results. Thus, future studies should include subgroup analyses which focus on specific populations (eg, individuals with ADHD and comorbid anxiety disorder).

As the body of literature examining the effects of MBIs on ADHD grows, it will be important for future researchers to report these possible influence factors (such as the gender of patients, and the subtype of ADHD) so that the relationship between these factors and intervention effectiveness can be examined, and perhaps these factors would be proved to have a significant impact on the intervention effectiveness.

5. Conclusion

In conclusion, this study has potential implications for mindfulness-based treatment and provide guidance for further investigations. The large effect of MBIs on the reduction of ADHD core symptoms was observed in this study, indicating that mindfulness-based treatment is a promising strategy to reduce ADHA symptoms. But the research exploring the effectiveness of mindfulness-based treatment is still in its infancy and some relevant questions remain to be solved. More methodologically rigorous studies are needed to explore how the variables moderate the effectiveness of mindfulness-based treatment. Meantime, more attention should be paid to investigate the association between the individual mindfulness facet and the improvement of symptoms in individuals with ADHD and the long-term effect of mindfulness-based treatment.

Author contributions

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