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Mind–body intervention for post-traumatic stress disorder in adolescents: a systematic review and network meta-analysis

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Abstract

Background Post-traumatic stress disorder (PTSD) is a potentially disabling condition that can lead to long-term impairments, with a significant proportion of adolescents being affected by trauma. Studies have suggested that trauma-focused cognitive behavioral therapy (TF-CBT) is an effective treatment for PTSD in adolescents, however, little is known about the relative advantages of different mind–body interventions. The network meta-analysis aims to evaluate and compare the efficacy of various mind–body interventions in alleviating PTSD symptoms in adolescents.

Methods A systematic search was conducted across multiple databases including PubMed, Embase, Web of Science, Scopus, The Cochrane Library, CNKI, WFDSP, and VIP databases. Randomized controlled trials (RCTs) evaluating the effects of mind–body interventions on PTSD in adolescents were included. A network meta-analysis (NMA) was conducted to evaluate the effectiveness of various mind–body intervention therapies using the Surface Under the Cumulative Ranking curve (SUCRA). SUCRA calculates the mean of the cumulative percent area under the curve for each therapy, providing a comprehensive ranking of treatment efficacy. The primary outcomes measured were changes in PTSD symptom scores post-treatment and at follow-ups ranging from 1 to 12 months.

Results A total of 20 studies involving 5 interventions and 2085 adolescents were included in the analysis. No inconsistencies were found between direct and indirect evidence. TF-CBT consistently demonstrated the most significant effect in reducing PTSD symptoms compared to routine care and no-treatment groups. The ranking of intervention efficacy from highest to lowest was as follows: TF-CBT (SUCRA = 87.3%), meditation, CBT, yoga combined with meditation and mindfulness (SUCRA = 32.3%). Due to limited evidence, the follow-up results for PTSD symptom changes remained inconclusive.

Conclusion Five mind–body interventions were found to be effective in treating PTSD symptoms in adolescents, with TF-CBT emerging as the most effective treatment. Findings suggest that yoga combined with meditation and mindfulness may have promising effects, however, further research is needed to confirm these results due to the limited evidence available.

Keywords Mind–body interventions, Adolescents, Post-traumatic stress disorder, Systematic review, Network meta-analysis

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Background

Post-traumatic stress disorder (PTSD) is a psychological condition that arises as a consequence of directly or indirectly experiencing or witnessing severe traumatic events. Such as natural disaster, war, sexual assault [1–3]. Although the degree of exposure to traumatic events varies among different populations, the susceptibility to developing PTSD following comparable traumatic experiences exhibits cultural variations [4]. The prevalence of PTSD is notably higher among military veterans [5–8] and professionals in high risk of in high-risk occupations [9] including law enforcement officers [10], firefighters [11], and emergency medical personnel [12, 13]. The highest incidence rates are rates are reported among individuals who have experienced sexual assault [14, 15], combat exposure [16], and childhood abuse [17]. PTSD has profound implications for affected individuals, significantly impairing their daily functioning, occupational performance, academic pursuits, and interpersonal relationships [18]. In the absence of timely intervention and psychological support, the disorder may precipitate a progressive decline in emotional, behavioral, and cognitive well-being, potentially culminating in suicidal ideation and behavior [19]. For instance, exposure to childhood maltreatment has been identified as a significant risk factor for suicide in later life [20]. Furthermore, individuals diagnosed with PTSD demonstrate an increased propensity for substance dependence, which exacerbates the burden of substance abuse and addiction, imposing a substantial socioeconomic and public health challenge [21]. These findings underscore the profound impact of post-traumatic stress disorder (PTSD) on diverse societal groups, jeopardizing individual health, family stability, and posing a latent risk to society at large.

More than half of the global population of children and adolescents have been exposed to potentially traumatic events [22, 23], with the majority of PTSD cases in adolescents being attributable to adverse childhood experiences [24]. Exposure to various forms of trauma during childhood, such as physical abuse [25] and witnessing domestic violence [26], can result in diminished engagement in novel activities during early developmental stages and a lack of interest in growth-related opportunities during adolescence. The psychological and developmental consequences of PTSD are often long-lasting [27, 28] exerting a profound influence on broader aspects of adolescent development. As individuals progress into adolescence, they may exhibit diminished self-esteem and underdeveloped personality traits [29], leading to social withdrawal, alienation from peers, and an overall sense of hopelessness regarding their future aspirations [30].

In light of the diverse emotional, behavioral, and psychological manifestations of PTSD in adolescents and its long-term repercussions, researchers worldwide have proposed a range of therapeutic approaches, encompassing both conventional pharmacological treatments and various forms of complementary and alternative medicine (CAM) therapies. interventions commonly involve the administration of [31], anxiolytics [32], or hypnotics [33]. However, due to considerable interindividual variability and the potential for adverse effects, a substantial proportion of patients fail to achieve an optimal therapeutic response [34]. Consequently, complementary therapies have emerged as viable alternatives these limitations. For instance, yoga and meditation are believed to mitigate stress and PTSD symptoms by fostering integration of bodily functions, breathing patterns, cognitive processes, and emotional regulation [35]. Cognitive behavioral therapy (CBT) has been demonstrated to effectively assist individuals in managing the emotional and cognitive distress associated with traumatic experiences [36], Additionally, traditional mind–body interventions such as tai chi and qigong, which combine integrate physical movement with controlled breathing and deep relaxation techniques, have shown potential in promoting mind–body equilibrium, thereby alleviating anxiety and stress [37].

The aforementioned interventions are collectively classified as mind–body interventions, with the majority falling under the category of mind–body therapies (MBT), a therapeutic approach grounded in the understanding of the intricate interplay between mental and physical processes. These interventions are designed to alleviate the impact of stress and tension while promoting overall physical and psychological well-being [38]. Mind–body therapies have increasingly been employed as an alternative strategy for mitigating PTSD symptoms. Numerous systematic reviews and meta-analyses have evaluated the efficacy of psychological and psychosocial treatments for PTSD in children and adolescents [39–41]. Current consensus indicates that Trauma-Focused Cognitive Behavioral Therapy (TF-CBT), a structured, therapist-guided, component-based, and evidence-supported intervention for adolescent PTSD [42], primarily employs trauma-specific cognitive, behavioral, and cognitive-behavioral techniques in conjunction with exposure therapy, proving to be an effective treatment modality. Previous studies have provided limited comparisons of therapeutic interventions within relatively small sample sizes and have synthesized direct evidence from randomized controlled trials (RCTs) using conventional meta-analytic methodologies. However, this approach is inherently constrained in its ability to determine the relative effectiveness of different interventions, as direct comparisons are only

feasible within clinical trials that juxtapose two or more treatments.

Network meta-analysis (NMA) represents an extension of conventional meta-analysis methodologies, accommodating complex data structures that encompass multiple treatment comparisons, such as A versus B, B versus C, and A versus C trials [43]. By integrating both direct and indirect comparisons, NMA enhances the estimation of the relative effectiveness between treatment options. This analytical approach enables the evaluation of interventions that have not been directly compared within randomized controlled trials (RCTs). Provided that the treatments are interlinked within an "evidence network"—where each treatment is directly compared to at least one other treatment under investigation—NMA facilitates the simultaneous estimation of the relative efficacy of all included interventions [44, 45].

The objective of this study was to undertake a comprehensive evaluation of the comparative efficacy of mind–body therapy (MBT) and other mind–body intervention modalities in the treatment of adolescents diagnosed with post-traumatic stress disorder (PTSD) through the use of a network meta-analysis (NMA). By methodically comparing and ranking a multitude of mind–body interventions, this study addresses a crucial gap in the extant literature on mind–body interventions for treating adolescents with PTSD. It provides a scientific foundation for clinicians in developing non-pharmacological treatment strategies and informs future research directions.

Methods

Search strategy

The search, inclusion, screening, and exclusion criteria for the literature in this study were developed in strict accordance with the process specified in the PRISMA entry and in line with the PICOS principles of empirical medicine [46]. A comprehensive search strategy was employed, encompassing major databases such as PubMed, Embase, Web of Science, Scopus, The Cochrane Library, CNKI, WFDSP, and VIP databases. A review protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO), registration number 2024: CRD42024519131.

The search time frame was from the inception of each database to March 2024. Searches were conducted in February and March 2024, and the first data extraction took place on April 1, 2024, and the search strategy followed the PICOS principles:

(P) Population: adolescents with PTSD;
Intervention: Mind–body therapies, Includes Trauma Focused Cognitive Behavioural Therapy (TF-CBT), Cognitive Behavioural Interventions (CBT), Yoga, Mindfulness and Meditation.
(C) Control group: different interventions or routine care and appropriate rehabilitation were used in the control group;
(O) Outcome: any assessment of symptoms in patients with PTSD after treatment and at follow-up;
(S) Type of study: randomized controlled trial.

The search strategy is shown in Table 1, with the Chinese search terms (Post-Traumatic Stress Disorder AND adolescents) AND (mind–body therapies OR mind–body interventions OR mind–body exercises OR psychotherapy OR trauma-focused cognitive behavioural therapy OR cognitive-behavioural therapies OR yoga OR meditation OR mindfulness) AND (randomized controlled trials OR controlled clinical trials) for example, in PubMed.

Inclusion criteria

The incorporation of mind–body therapies into MBT is predicated on a combination of active body movement and mindfulness exercises, including yoga and meditation. Conversely, massage, aromatherapy, acupuncture, and progressive muscle relaxation constitute passive treatment modalities that do not involve attention regulation, positive mindfulness practice, or physical activity. Consequently, these interventions were not considered in the present study.

The criteria for inclusion in the eligible articles were as follows. (1) the study design was a Randomized Controlled Trial (RCT); (2) the experimental sample was predominantly composed of adolescents between the ages of 6 and 24 years who had received a diagnosis of post-traumatic stress disorder (PTSD) from a certified psychiatrist.; (3) the intervention group using different mind–body therapies intervention methods (e.g., cognitive-behavioural therapy, mindfulness, yoga, and meditation) in the experimental group versus a control group using different interventions (e.g., usual care and rehabilitation); (4) the primary outcome indicators should include data related to PTSD symptoms, depression, and anxiety; and (5) the language of the literature could only be Chinese or English.

Exclusion criteria

Exclusion criteria included (1) non-randomized controlled trial (RCT) experiments, experimental animal studies, descriptive and investigative literature, review literature, secondary studies, academic conference papers, and repetitively published literature; (2) subjects who were non-adolescents with PTSD and who did not have other clinical symptoms and characteristics. Studies with ambiguous or no data available for analysis were

Table 1 PubMed search strategy

#1 Stress Disorders, Post-Traumatic [MeSH Terms]
#2 Post-Traumatic Stress Disorder [Title/Abstract] OR Stress Disorder, Post-Traumatic [Title/Abstract] OR Neuroses, Post-Traumatic [Title/Abstract] OR Neuroses, Post Traumatic [Title/Abstract] OR Post-Traumatic Neuroses [Title/Abstract] OR PTSD [Title/Abstract] OR Neuroses, Posttraumatic [Title/Abstract] OR Posttraumatic Neuroses [Title/Abstract] OR Post-Traumatic Stress Disorders [Title/Abstract] OR Post Traumatic Stress Disorders [Title/Abstract] OR Posttraumatic Stress Disorders [Title/Abstract] OR Posttraumatic Stress Disorder [Title/Abstract] OR Stress Disorder, Posttraumatic [Title/Abstract] OR Stress Disorders, Posttraumatic [Title/Abstract] OR Post Traumatic Stress Disorder [Title/Abstract] OR Stress Disorder, Post Traumatic [Title/Abstract] OR Delayed Onset Post-Traumatic Stress Disorder [Title/Abstract] OR Delayed Onset Post Traumatic Stress Disorder [Title/Abstract] OR Chronic Post-Traumatic Stress Disorder [Title/Abstract] OR Chronic Post Traumatic Stress Disorder [Title/Abstract] OR Moral Injury [Title/Abstract] OR Injury, Moral [Title/Abstract] OR Moral Injuries [Title/Abstract] OR Acute Post-Traumatic Stress Disorder [Title/Abstract] OR Acute Post Traumatic Stress Disorder [Title/Abstract]
#3 #1 OR #2
#4 Young adult [MeSH Terms] OR Adolescent [MeSH Terms]
#5 Adolescence [Title/Abstract] OR Teenagers [Title/Abstract] OR Youth [Title/Abstract] OR Teen [Title/Abstract] OR Juvenile [Title/Abstract] OR AYA [Title/Abstract] OR college [Title/Abstract] OR Student [Title/Abstract] OR Young [Title/Abstract] OR University [Title/Abstract]
#6 #4 OR #5
#7 Mind-Body Therapies [Title/Abstract] OR Trauma-Focused Cognitive Behavioural Therapy [Title/Abstract] OR Cognitive Behavioural Therapy [Title/Abstract] OR Yoga [Title/Abstract] OR Meditation [Title/Abstract] OR Mindfulness [Title/Abstract]
#8 Mind-Body [Title/Abstract] OR Mind-Body Medicine [Title/Abstract] OR Mind Body Practice [Title/Abstract] OR Mindfulness-Based Cognitive Therapy [Title/Abstract] OR TF-CBT [Title/Abstract] OR Cognitive Behavioural Therapy [Title/Abstract] OR CBT [Title/Abstract] OR Cognitive Behavioural stress management [Title/Abstract] Transcendental Meditation [Title/Abstract] OR Meditation, Transcendental [Title/Abstract]
#9 #7 OR #8
#10 Randomized Controlled Trial [Publication Type] OR Controlled Clinical Trial [Publication Type] OR Randomized [Title/Abstract] OR RCT [Title/Abstract] OR Placebo [Title/Abstract]
#11 #3 AND #6 AND #9 AND #10

Additional legends

Intervention	Definition
TF-CBT (Trauma Focused Cognitive Behavioural Therapy)	A treatment specifically for post-traumatic stress disorder (PTSD) that helps patients deal with traumatic memories through cognitive behavioural therapy.
CBT (Cognitive Behavioural Therapy)	A widely used psychotherapeutic approach designed to help patients identify and change negative thought patterns and behaviors.
Yoga	A mind-body practice that combines body postures, breath control and meditation to help reduce stress and anxiety
Mindfulness	A practice of becoming aware of one's thoughts, emotions and bodily sensations in a non-judgmental manner through conscious attention to the experience of the current moment, with the aim of increasing self-awareness and emotional regulation.
Meditation	A practice that trains attention and awareness through specific techniques, such as focused breathing or repetition of a mantra, to achieve a state of mental calm and concentration, helping to reduce stress and enhance mental health.

also excluded; (3) instances where interventions were included with other interventions or provided data that were incompletely described or could not be converted; (4) Publications from non-core Chinese journals were excluded; and (5) studies on massage, acupuncture, and other similar passive mind–body therapies.

Literature screening

The research strategy was implemented by two researchers to import the obtained literature into Endnote X 9.1 software and to exclude duplicate literature. The selected studies were then independently screened based on their title and abstract. Z BJ and S XY were responsible for independently screening and extracting the literature, respectively. The complete text was then carefully read and screened according to the inclusion and exclusion criteria. The two researchers then met to discuss the results of the screening process, and if they were in agreement, the study was included. In the event of disagreement, a third researcher was consulted and, following discussion and agreement, a final decision was taken collectively.

Data extraction

Information extraction was performed on the final included literature, and the data and risk of bias of the included literature were recorded and summarized according to a predefined information extraction form. Data extraction included the following aspects: 1) basic information about the included literature (title, authors, year of publication, etc.); 2) characteristics and information about the subjects (sample size, age, gender, etc.); 3) specific information about the interventions and controls (type, duration, frequency, etc.); 4) assessment of

the quality of the literature; and 5) Outcome assessment (assessment tools) and follow-up.

Risk of bias assessment

The risk of bias was independently assessed by two researchers using the Cochrane Risk of Bias (ROB) assessment tool in Cochrane version 5.1.0 [47]. This tool encompasses seven domains: (1) generation of randomized sequences; (2) implicit treatment assignment; (3) blinding of study subjects or interveners; (4) blinding of outcome assessors; (5) completeness of the data results; (6) selective reporting of results; and (7) other biases. The evaluation of each item was conducted using the following categories: "low risk of bias", "high risk of bias", and "unclear". The categorisation of trials was undertaken on the basis of the number of components that were deemed to be at high risk of bias. Trials were designated as being at high risk (5 or more components), moderate risk (3 or 4 components), or low risk (2 or fewer components).

Statistical analysis

Stata 17.0 software the PRISMA-NMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Network Meta-Analysis) given that the outcome measures were continuous variables and the standardized mean difference (SMD) and 95% confidence intervals (CI) were employed as effect size metrics to synthesize the findings. All statistical tests were uniformly adjusted to an alpha level of 0.05. Heterogeneity among studies was assessed using the Q-test and I^2 statistic, while publication bias was evaluated through Egger's test. In the network meta-analysis, if a closed-loop structure was present in the network evidence plot, node-splitting analysis was conducted to assess inconsistency [48]. When the node-splitting analysis yielded a p-value greater than 0.05, a consistency model analysis was performed. Additionally, a node-splitting was method was employed to examine local inconsistency, and if the local inconsistency p-value was less than 0.05, the corresponding results were directly compared in a conventional meta-analysis. In NMA, the Surface Under the Cumulative Ranking curve (SUCRA) serves as a metric for quantifying and ranking the relative efficacy of various treatments. SUCRA is computed by determining the area under the cumulative ranking curve for each treatment across all potential ranking permutations, with values ranging from 0 to 1 [49]. Based on the SUCRA values for different outcomes, cluster ranking analysis was conducted to identify the optimal physical and psychological treatment group. Furthermore, a comparison-adjusted funnel plot was employed to assess publication bias.

Results

Literature screening process and results

A total of 962 English-language studies and 144 Chinese-language studies were identified through electronic databases searches, with an additional 8 articles manually retrieved from other sources. After the removal of duplicate records based on titles and abstracts, 528 articles remained for further assessment. A thorough full-text review resulted in the exclusion of 375 articles due to various reasons, including non-randomized controlled trial design, incomplete data, inappropriate publication types (e.g., conference proceedings, review articles), or failure to meet the predefined intervention criteria or target population. Consequently, a total of 20 studies were deemed eligible for inclusion in this analysis. The literature screening process is depicted in Fig. 1.

Basic characteristics of the included studies

A meta-analysis of 20 randomized controlled trials involving a total of 2085 adolescents diagnosed with PTSD was conducted. The experimental group received a variety of mind–body therapies, including eight involving trauma-focused cognitive-behavioural therapy (TF-CBT) [50–57], and five involved cognitive behavioural therapy (CBT) [58–62], 3 involved meditation [63–65], 2 involving yoga-meditation combination therapies [66, 67], and 2 studies involving mindfulness [68, 69]. The endpoints chosen to be measured varied across studies. Specifically, in the corpus of 20 studies under review, the Symptom Scale was uniformly employed as the primary outcome indicator. Additionally, the CPSS was utilized in 6 studies, the UCLA-PTSD RI in another 6, and the CRIES-13 in 3 studies. The remaining 6 studies adopted diverse instruments, namely the TSC-C, HTQ, IES-R, PCL-5, ETI-CA, and CROPS. The studies encompassed a diverse array of countries and regions, including five from the United States, three from mainland China, two from Northern Ireland, two from the United Kingdom, and one each from Norway, Iran, Thailand, Mexico, Germany, Colombia, South Africa, and the Netherlands. Of the 20 studies, 17 employed a 1-to-12-month post-intervention follow-up survey, and only four interventions (TF-CBT, CBT, meditation, and mindfulness) reported follow-up survey data in detail. Table 2 delineates the fundamental attributes of the incorporated literature.

Quality assessment of the included studies

Of the 20 studies, 16 mentioned the use of methods such as random number tables and computers to generate random sequences. Seventeen studies reported allocation concealment methods such as opaque sealed envelopes with markings or central allocation. Thirteen studies detailed blinding of patients, and only eight studies

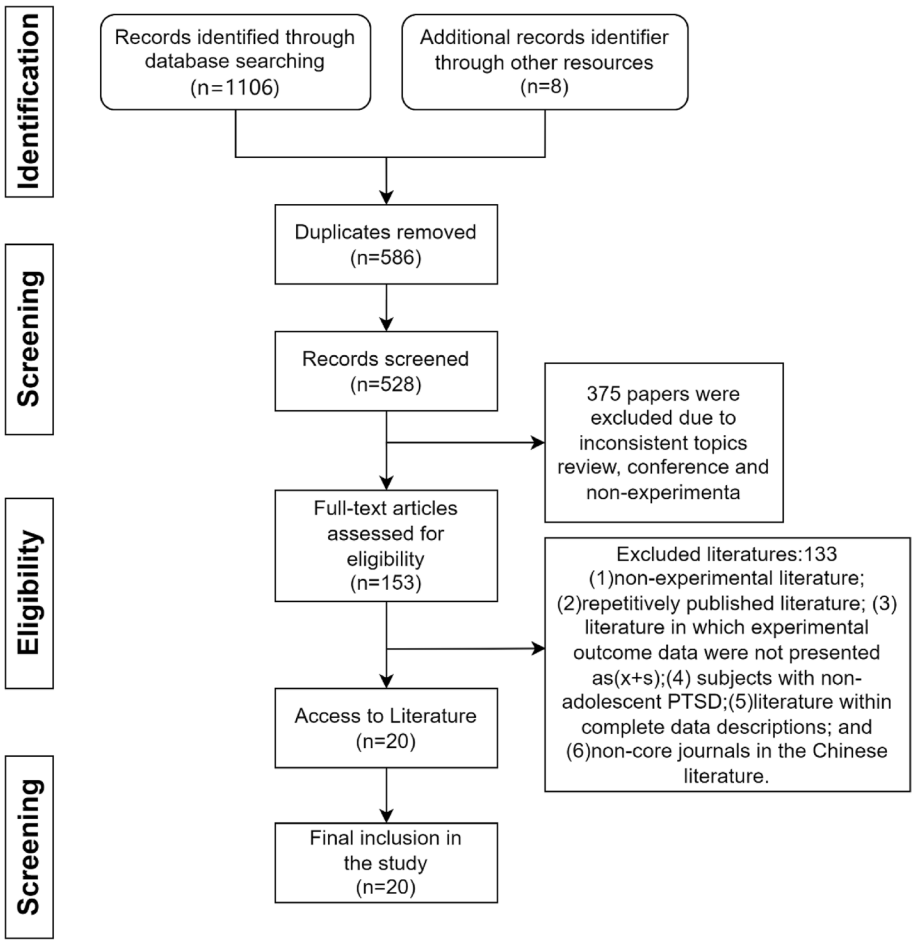

Fig. 1 Flow chart of literature screening

blinded those who assessed the results of the study. Data completeness was good in all 20 studies, with no selective reporting identified and one study did not clearly articulate the results of the research ethics review. The detailed assessment results are shown in Fig. 2.

Network meta-analysis

Evidence network and coherence analysis

The NMA results are shown in Fig. 3. The seven dots represent the seven interventions. A straight line between the dots indicates that there is a direct comparison between the interventions, and the thickness of the line indicates the number of direct comparisons between the two interventions. Both metrics are for seven interventions (including the blank control) and incorporate the same interventions. The mind–body therapies intervention group included TF-CBT, meditation, CBT, yoga combined with meditation, and mindfulness. The control group was conventional treatment or no treatment. The presence of closed loops in the network between interventions was tested for consistency and inconsistency of all p-values for indirect and direct comparisons between all studies. Since all p-values were >0.05, the effect of consistency between studies was acceptable.

Indirect comparisons between different mind–body interventions

As a result of the NMA (Fig. 3 and Fig. 4), the effect sizes of CBT, yoga combined with meditation, and mindfulness interventions for PTSD symptoms in adolescents were not statistically significant when compared to the conventional treatment group [SMD = −1.14, 95%CI (−0.58, 1.7)], [SMD = −0.41, 95%CI (−0.99, 1.82)], [SMD = −0.05, 95%CI (−1.07, 1.16)]. In contrast, the combined effect of the 2 measures, TF-CBT and meditation interventions, in intervening with PTSD symptoms in adolescents and young adults was significantly better than that of the control group [SMD = −1.14, 95%CI (−0.58, 1.7)], [SMD = −0.97, 95%CI (0.07, 1.86)]. The combined effect sizes of yoga combined with meditation as well as mindfulness interventions on PTSD symptoms in adolescents were not statistically significant

Table 2 Characteristics of the studies included in the meta-analysis

Author & Year	Country	Sample size (Male/ Female)	T/C	Ages (T/C) (Mean ± SD or Range)	Intervention cycle, Frequency, Duration	Intervention method	Type of control group	Outcome assessments	Follow-up
Cohen, J. A [50] 2005	USA	82 (56/26)	41/41	8–15 11.4/ 10.8	12 weeks, 1 time/week, 45 min/time	TF-CBT	UC	TSC-C	Yes 12-month
Giannopoulou, I [58] 2006	UK	20 (9/11)	10/10	8–12 9.6	12 weeks, 1 time/week, 45 min/time	CBT	WL	CRIES-13	Yes 18-month
Smith, P [51] 2007	UK	24 (12/12)	12/12	13.89 ± 2.82 (14.45 ± 2.7/13.33 ± 2.95)	10 weeks, 1 time/week 60 min/time	TF-CBT	WL	CAPS-CA; CPSS	Yes 6-month
Gordon, J. S [63] 2008	USA	82 (62/20)	38/40	14–18 16.3	6 weeks, 2 time/week 120 min/time	Meditation	WL	HTQ	Yes 3-month
Shooshtary, M. H [59] 2008	Iran	168 (74/91)	135/33	15.5 ± 2.3 (15.3 ± 2.7/16.20 ± 2.24)	4 weeks 1 time/week 120 min/time	CBT	WL	IES-R	No
McMullen, J [52] 2013	Northern Ireland	50[a]	25/25	15.8 ± 1.4 (15.9 ± 1.3/15.6 ± 1.4)	5 weeks 3 time/week 120 min/time	TF-CBT	WL	UCLA-PTSD RI	Yes 3-month
O'Callaghan, P [53] 2013	Northern Ireland	52[b]	24/28	12–17	5 weeks 3 time/week 120 min/time	TF-CBT	WL	UCLA-PTSD RI	Yes 3-month
Chen, Y [60] 2014	China	40 (13/27)	10/10/12	14.5 ± 0.71	6 weeks 1 time/week 60 min/time	CBT	UC	CRIES-13	Yes 3-month
Jensen, T. K [54] 2014	Norway	156 (32/124)	79/77	10–18 15.1 ± 2.2	13 weeks 1 time/week 90 min/time	TF-CBT	UC	CPSS; CAPS-CA	Yes
Culver, K. A [66] 2015	USA	76 (44/32)	34/27	7–17 11.23 ± 2.15	8 weeks 2 time/week 45 min/time	Yoga Meditation	WL	UCLA-PTSD RI	Yes
Pityaratstian, N [61] 2015	Thailand	36 (10/26)	18/18	10–15 12.25 ± 1.27	3 days 1 time/day 120 min/time	CBT	WL	CRIES-13; UCLA-PTSD RI	Yes 1-month
Murray, L. K [55] 2015	USA	257 (129/128)	131/126	5–18 (14.02 ± 2.77/13.29 ± 2.99)	16 weeks 1 time/week 60–90 min/ time	TF-CBT	UC	UCLA-PTSD RI	Yes 1-month
Shein-Szydlo, J [62] 2016	Mexico	100 (36/64)	50/49	12–18 (14.75 ± 1.71/15.05 ± 1.78)	12 weeks 1 time/week 60 min/time	CBT	WL	CPSS	Yes 3-month
Tong Weilong [68] 2019	China	40 (11/29)	20/20	12–18 (16.05 ± 2.12/15.62 ± 2.68)	8 weeks 2 time/week 45 min/time	Mindfulness	TF-CBT	UCLA-PTSD RI	No
Dorsey, S [56] 2020	USA	640 (320/320)	320/320	7–13	12 weeks 1 time/week 60 min/time	TF-CBT	UC	CPSS	Yes 12-month
Kananian, S [67] 2020	Germany	24[a]	11/12	21.9 ± 3.4 (21 ± 3.4/22.8 ± 3.3)	6 weeks 2 time/week 90 min/time	Yoga Meditation	WL	PCL-5	Yes 12-month
Roque-Lopez, S [69] 2021	Colombia	44[b]	22/22	13–16 (14 ± 1.1/14.1 ± 1.2)	1 week 7 time/week	Mindfulness	UC	CPSS	Yes 1-month
Zhi Licong [64] 2021	China	42	21/21	11–18	5 weeks 6 time/week 100 min/time	Meditation	UC	ETI-CA	No

Table 2 (continued)

Author & Year	Country	Sample size (Male/Female)	T/C	Ages (T/C) (Mean ± SD or Range)	Intervention cycle, Frequency, Duration	Intervention method	Type of control group	Outcome assessments	Follow-up
Kaminer, D [57] 2023	South Africa	75 (21/54)	37/38	11–19 14.92 ± 1.84	8 weeks 1 time/week 45 min/time	TF-CBT	UC	CPSS	Yes 3-month
Schuurmans, Angela A. T [65] 2023	Nether-lands	77 (45/32)	37/40	10–18 (14.93 ± 2.63/15.31 ± 1.91)	8 weeks 2 time/week 15–20 min/time	Meditation	UC	CROPS	Yes 2-month

WL Waitlist, *UC* Usual Care, *TSC-C* Trauma Symptom Checklist for Children, *CRIES-13* 13-item Children's Revised Impact of Events Scale, *CAPS-CA* Clinician Administered PTSD Scale for Children and Adolescents, *HTQ* Harvard Trauma Questionnaire, *IES-R* Impact of Event Scale–Revision, *UCLA-PTSD RI* UCLA-PTSD Reaction Index, *CPSS* Child PTSD Symptom Scale, *PCL-5* The PTSD Checklist for DSM-5, *ETI-CA* Essen Trauma Inventory for Children and Adolescents, *CROPS* Child Report of Posttraumatic Symptoms

[a] Only males

[b] Only females

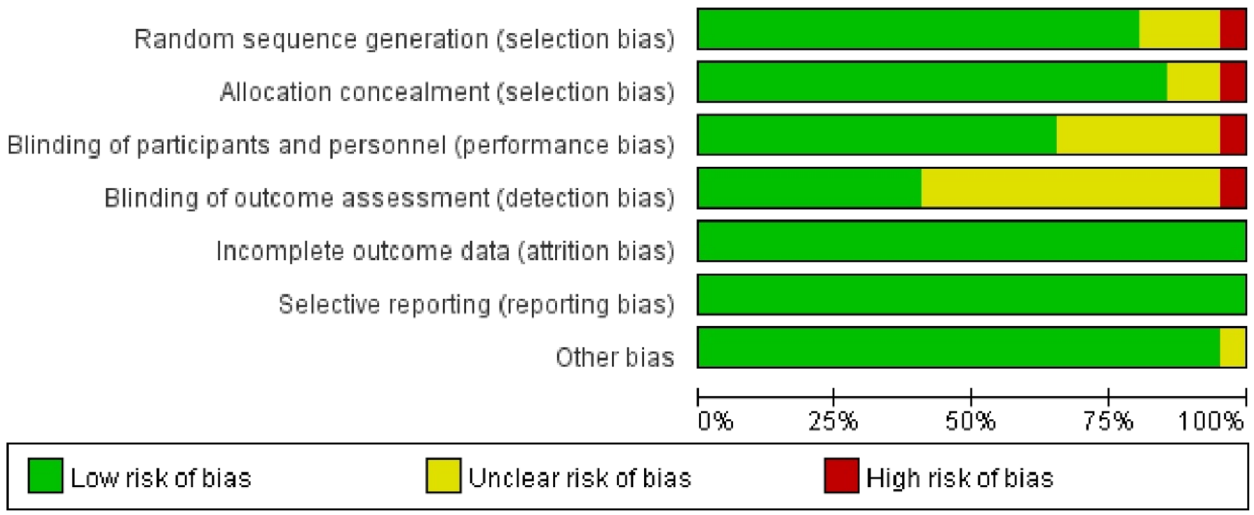

Fig. 2 Risk of bias graph

compared to the no intervention group [SMD = −0.91, 95%CI (−0.26, 2.07)], [SMD = −0.54, 95%CI (−0.76, 1.84)], whereas the 3 measures of the TF-CBT, meditation, and CBT interventions The combined effects of the interventions on PTSD symptoms in adolescent youth were significantly better than those of the control group [SMD = −1.63, 95%CI (0.89, 2.37)], [SMD = −1.46, 95%CI (0.47, 2.46)], and [SMD = −1.26, 95%CI (0.52, 2)].

Results of the cross-comparisons between the five measures showed that TF-CBT was significantly more effective than meditation, CBT, yoga combined with meditation, and mindfulness for a comprehensive intervention for PTSD symptoms in adolescents [SMD = −0.17, 95%CI(−1.16, 0.82)], [SMD = −0.37, 95%CI(−1.36, 0.62)], [SMD = −0.73, 95%CI (−2.10, 0.65)], [SMD = −1.09, 95%CI (−2.21, 0.03)]. Meditation was significantly better than CBT, yoga combined with meditation and mindfulness [SMD = −0.2, 95%CI (−1.40, 0.99)], [SMD = −0.56, 95%CI (−2.09, 0.97)], [SMD = −0.92, 95%CI (−2.33, 0.49)]. CBT was significantly better than yoga combined with meditation and mindfulness [SMD = −0.35, 95%CI(−1.73, 1.02)], [SMD = −0.72, 95%CI(−2.16, 0.72)], while yoga combined with meditation was significantly better than mindfulness [SMD = −0.37, 95%CI(−2.11, 1.37)] (Table 3).

Possible ranking of effectiveness of mind–body interventions

Combining effect size and the SUCRA method to rank the effectiveness of five interventions for PTSD in adolescents, it was found that TF-CBT was ranked first in

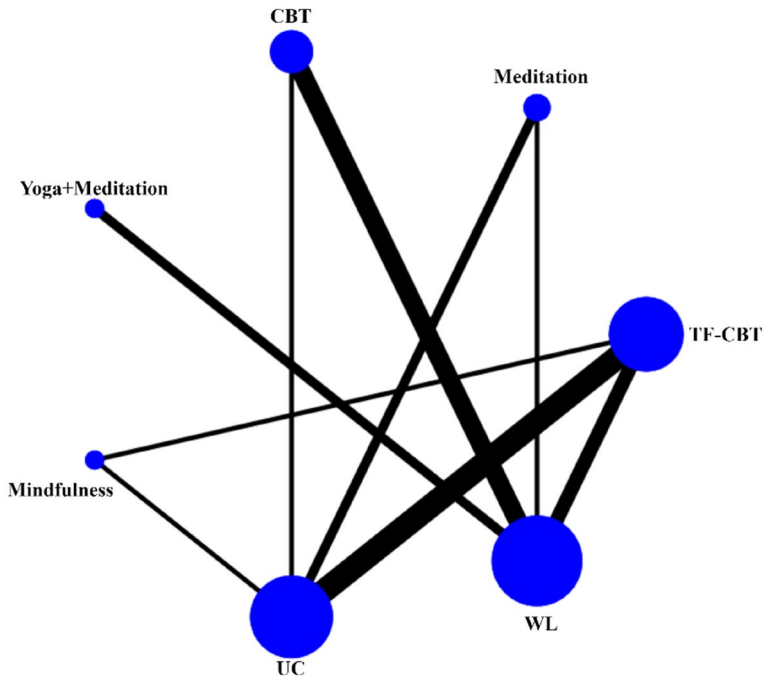

Fig. 3 Network graph of interventions

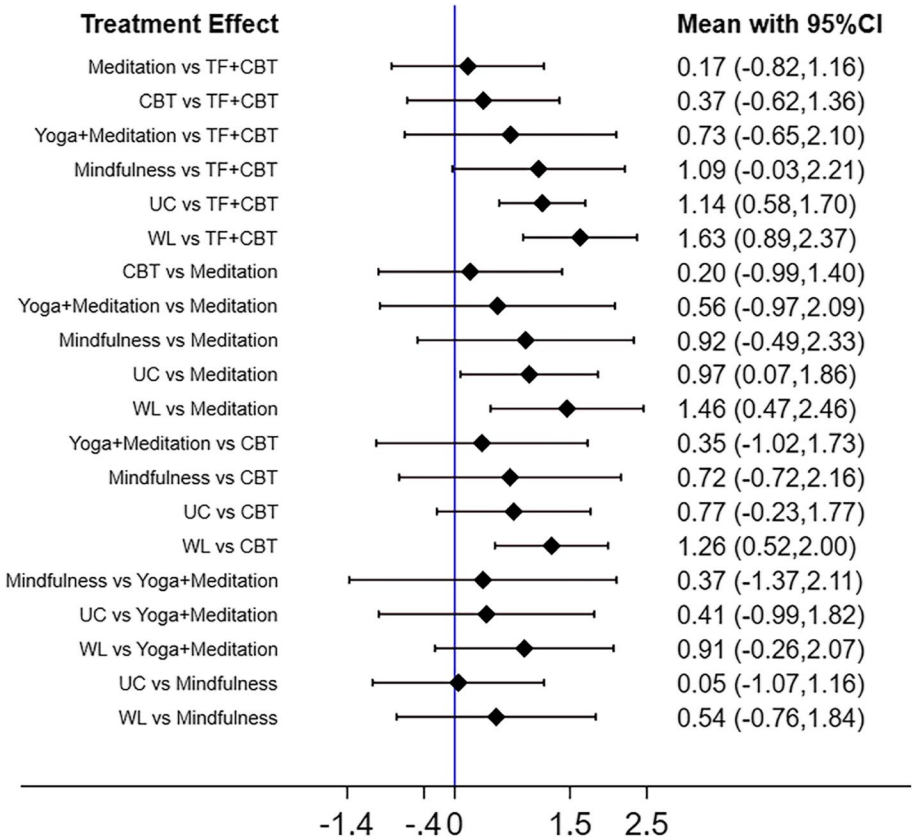

Fig. 4 Forest plot for NMA

Table 3 Results of cross-comparisons between Mind–body interventions

Relative effects				
TF + CBT				
−0.17 (−1.16, 0.82)	**Meditation**			
−0.37 (−1.36, 0.62)	−0.20 (−1.40, 0.99)	**CBT**		
−0.73 (−2.10, 0.65)	−0.56 (−2.09, 0.97)	−0.35 (−1.73, 1.02)	**Yoga + Meditation**	
−1.09 (−2.21, 0.03)	−0.92 (−2.33, 0.49)	−0.72 (−2.16, 0.72)	−0.37 (−2.11, 1.37)	**Mindfulness**

the SUCRA for effectiveness in reducing PTSD symptom scores (SUCRA: 87.3%), with a probability of 46%. The subsequent rankings of effectiveness of mind–body interventions for PTSD in adolescents were, in descending order, meditation (SUCRA = 77%), CBT (SUCRA = 67.4%), yoga combined with meditation (SUCRA = 50.7%), and mindfulness (SUCRA = 32.3%), with all interventions outperforming the conventional treatment group (SUCRA = 28.8%) and no treatment group (SUCRA = 6.5%). Thus, the rank order of probability of effectiveness of interventions for PTSD symptoms in adolescents was TF-CBT > Meditation > CBT > Yoga + Meditation > Mindfulness > UC > WL. Specific details are shown in Table 4, Fig. 5 and Table 5.

Comparison of different mind–body interventions between follow-ups

Results of the cross-comparisons between the 4 measures showed that CBT was significantly better than TF-CBT, meditation, and mindfulness [SMD = 0.75, 95%CI (0.09, 1.41)], [SMD = 1.49, 95%CI (0.87, 2.12)], [SMD = −1.05, 95%CI (−1.92,—0.17)].TF-CBT was significantly better than meditation with mindfulness [SMD = −0.74, 95%CI (−1.17, −0.31)], [SMD = −0.29, 95%CI (−0.9, 0.31)]. And mindfulness was superior to meditation [SMD = 0.45, 95%CI (−0.27, 1.16)] (Tables 6 and 7).

Combining effect size and the SUCRA method (Table 8, ranking the effectiveness of the four interventions found that CBT ranked first in SUCRA (SUCRA = 98.9%). The subsequent rankings of effectiveness of mind–body interventions for PTSD in adolescents were TF-CBT (SUCRA = 60%), mindfulness (SUCRA = 31.3%), and meditation (SUCRA = 2.4%). Thus, the likelihood of effectiveness of interventions for PTSD symptoms in adolescents at follow-up was ranked as CBT > TF-CBT > Mindfulness > Meditation.

Publication bias detection and sensitivity analysis

A funnel plot was created to check for potential publication bias. Visual assessment of the funnel plot indicated that there was a potential for publication bias. Therefore, a further Egger's test was performed, which showed that the level of bias was not significant ($Pr > |t| = 0.558$, $p > 0.05$). The details are shown in Fig. 6. The second sensitivity analysis, conducted after excluding individual studies, showed that the statistical significance of the results of all studies did not change significantly. This confirms the robustness of the findings.

Discussion

The objective of this NMA was to evaluate and compare the relative therapeutic effects of various mind–body interventions on post-traumatic stress disorder (PTSD) symptoms in adolescents, and to juxtapose these interventions against a control group. The results demonstrated that all five MBTs—TF-CBT, meditation,

Table 4 Ranked probability of effectiveness of Mind–body interventions

Rank	Treatments						
	TF-CBT	**Meditation**	**CBT**	**Yoga Meditation**	**Mindfulness**	**UC**	**WL**
Best	46	28.5	13.6	10.4	1.5	0	0
2nd	35.8	28.5	21.2	10	4.5	0	0
3rd	14.6	24.2	33.4	16.2	9	2.6	0
4th	3.4	14.5	22	26.8	17.9	14.8	0.5
5th	0.2	3.5	7.3	15.7	25.3	41.5	6.4
6th	0	0.6	2.4	15.2	22.2	34.8	24.8
Worst	0	0.1	0.1	5.6	19.6	6.3	68.3

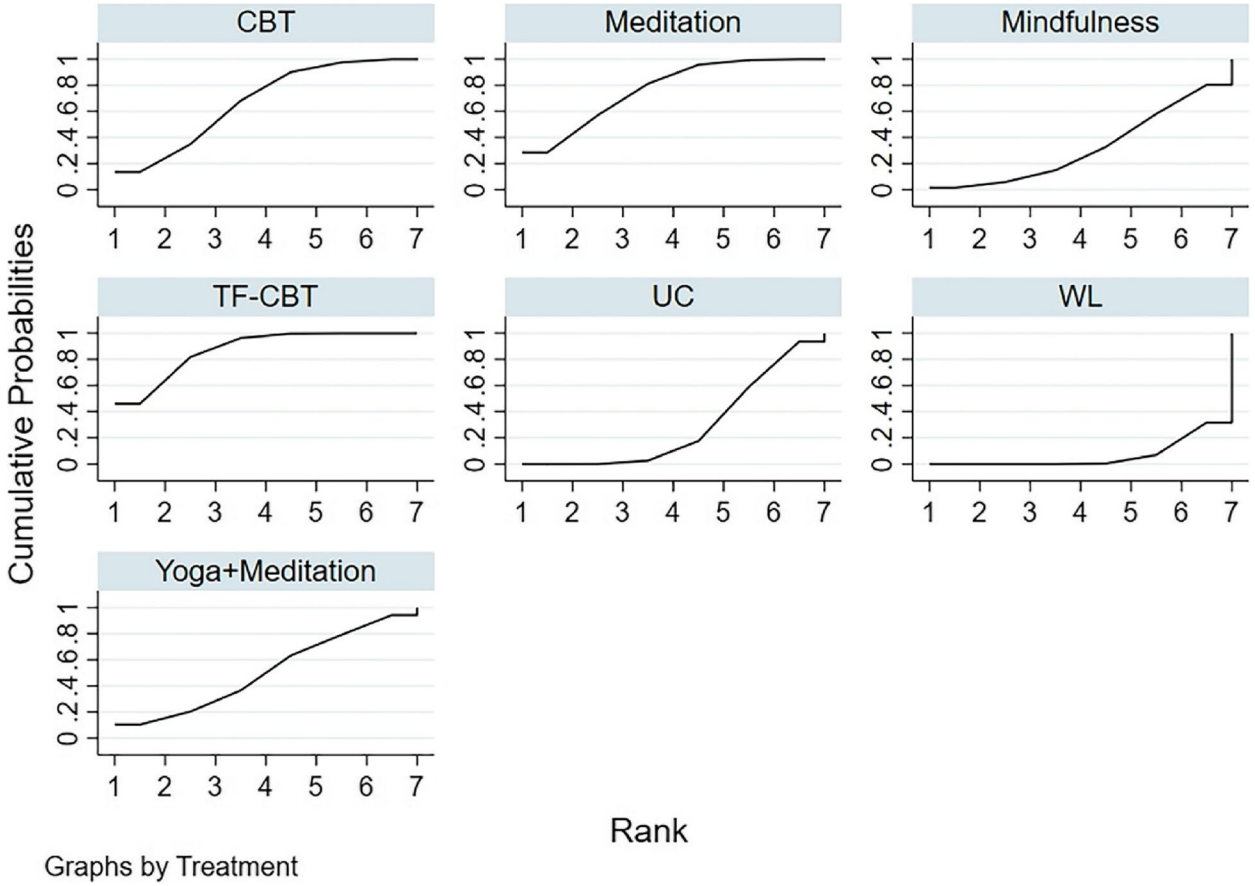

Fig. 5 SUCRA plot of effectiveness of Mind–body interventions

Table 5 SUCRA values for the effectiveness of Mind–body intervention

Treatment	SUCRA	PrBest	MeanRank	Sorting
TF-CBT	87.3	46	1.8	1
Meditation	77	28.5	2.4	2
CBT	67.4	13.6	3.0	3
Yoga + Meditation	50.7	10.4	4.0	4
Mindfulness	32.3	1.5	5.1	5
UC	28.8	0.0	5.3	6
WL	6.5	0.0	6.6	7

Table 6 Indirect comparisons between follow-ups of different Mind–body interventions

Relative effects		
TF + CBT		
−0.74 (−1.17, −0.31)	Meditation	
0.75 (0.09, 1.41)	1.49 (0.87, 2.12)	CBT
−0.29 (−0.90, 0.31)	0.45 (−0.27, 1.16)	−1.05 (−1.92, −0.17) Mindfulness

Table 7 Ranked probability of effectiveness of Mind–body interventions at follow-up

Rank	Treatments			
	TF-CBT	Meditation	CBT	Mindfulness
Best	0.9	0.0	95.4	0.7
2nd	13	0.0	3.9	5.2
3rd	71.3	0.1	0.6	12.9
4th	14.7	0.6	0.1	23.6
Worst	0.0	88.5	0.0	11.1

Table 8 SUCRA values for the effectiveness of Mind–body intervention

Treatment	SUCRA	PrBest	MeanRank	Sorting
CBT	98.9	95.4	1.1	1
TF-CBT	60.0	0.9	3.0	2
Mindfulness	31.3	0.7	4.4	3
Meditation	2.4	0.0	5.9	4

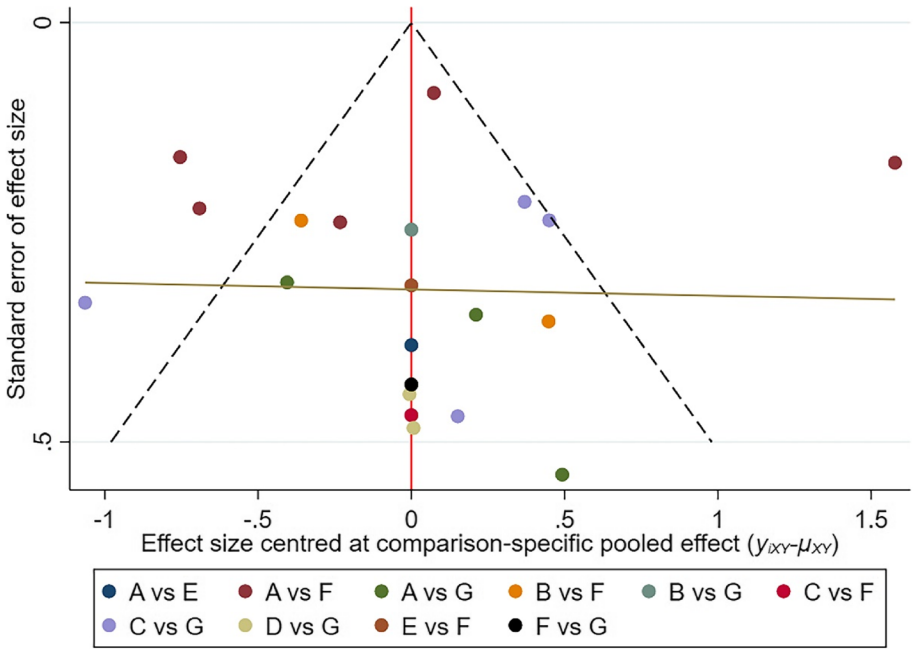

Fig. 6 Funnel plot on publication bias

CBT, yoga combined with meditation and mindfulness—significantly alleviated PTSD symptoms in adolescents compared to the control group (i.e., standard care and no treatment). These findings are consistent with previous reviews on the effectiveness of MBIs, such as TF-CBT, mindfulness, yoga, and meditation, in reducing PTSD symptoms among veterans [70], adults [71], and children [72]. In this study, a broader range of mind–body was included, and quantitative evidence was provided, further reinforcing the efficacy of these therapeutic approaches. The comprehensive evaluation of different intervention modalities enhances our understanding of their relative effectiveness and supports their application in clinical and community settings.

The results of this NMA indicate that five therapeutic modalities were included in the final 20 papers: TF-CBT, meditation, CBT, yoga combined with meditation, and positive thinking. Pairwise comparisons revealed no significant differences between the five mind–body therapies. According to the effect size and ranking probability of SUCRA values, TF-CBT exhibited the strongest effect on PTSD symptoms in adolescents (SUCRA: 87.3%), followed by meditation (SUCRA: 77%). The analysis of the follow-up phase indicated that CBT was more significant in terms of long-term effects (SUCRA: 98.9%). In summary, TF-CBT has been demonstrated to be the most efficacious intervention in the therapeutic reduction of PTSD symptoms, a finding that is consistent with the results of other reviews on TF-CBT, and that CBT is more effective in sustaining patients' improvement.

Effective psychological interventions for PTSD typically encompass core therapeutic components such as psychoeducation, imaginal exposure, cognitive processing, cognitive restructuring, and meaning-making [73]. The advantages of TF-CBT in the treatment of adolescent PTSD lie in its structured framework, trauma-specific focus, strong empirical support, emphasis on family involvement, and individualized therapeutic approach. These attributes have established TF-CBT as a widely endorsed and extensively implemented evidence-based intervention. Furthermore, all effective therapeutic approaches adhere to a structured framework and are delivered by healthcare professionals with specialised training. These professionals are required to undergo regular supervision and continuous professional development to ensure the fidelity and effectiveness of the interventions. The findings of this study further indicate that combined intervention approaches may not necessarily yield superior outcomes compared to single-modality treatments. A study conducted in the United States demonstrated that mindfulness meditation resulted in significant improvements in adolescents' working memory capacity (WMC) compared to both the Hatha yoga and waitlist control groups. However, no statistically significant differences were observed between the Hatha yoga and waitlist control groups in terms of stress or

anxiety reduction [74]. This suggests that mindfulness meditation may be more effective than yoga, as it primarily focuses on cultivating internal awareness and self-reflection, whereas yoga typically incorporates physical movements and postures. The observed efficacy of mindfulness meditation as a standalone intervention may be attributed to its capacity to provide an individualized, self-paced, and introspective experience, allowing adolescents to engage in therapeutic practice at their own pace and according to their specific needs without the potential distractions introduced by physical activity. In contrast, yoga which places greater emphasis on physical coordination and movement, may not sufficiently address the emotional and cognitive processing needs of adolescents with PTSD. Consequently, mindfulness meditation appears to be a more suitable intervention for addressing the complex psychological and emotional demands of this population.

The study results indicate that among the five assessed mind–body interventions, mindfulness intervention demonstrated the least effectiveness. This may attributed to factors such as lack of focused intervention targets, an absence of a structured therapeutic framework, insufficient coping strategies, and inadequate attention to cognitive aspects. In contrast, CBT and TF-CBT offer a more structured and systematic treatment approaches, thereby exhibiting superior efficacy in alleviating symptoms of PTSD in adolescents. However, it has also been suggested that mindfulness intervention remains an underutilised approach in the treatment of adolescent PTSD [75]. While mindfulness interventions have been extensively studied in adults with PTSD, research on their application in traumatised adolescents remains limited. Given its emphasis on non-judgmental awareness, mind–body integration, and group-based support, mindfulness intervention may hold unique benefits for adolescents coping with trauma. Therefore, further research is warranted to better understand the potential of mindfulness interventions in this population and to provide robust evidence supporting their effectiveness.

Analysis follow-up outcomes suggests that CBT seems to be the most effective intervention for maintaining improvement in PTSD symptoms over a follow-up period of 1 to 12 months, followed by TF-CBT, mindfulness and meditation. Although yoga combined with meditation has been reported to contribute to symptom maintenance to some extent, the lack of supporting data prevents definitive conclusions [76]. Given the limited evidence base, these findings should be interpreted with caution.

To the best of our knowledge, this is the first NMA to evaluate the effectiveness of mind–body interventions for children and adolescents with PTSD. This study aims to inform clinical guidelines by providing a treatment framework that balances personalization and flexibility, offering a more comprehensive and holistic therapeutic approach. The NMA methodology allows for the integration of evidence from multiple interventions, enabling both direct and indirect comparisons while maintaining the rigor of randomization. Consistency analysis conducted within the NMA revealed no significant discrepancies between direct and indirect evidence regarding changes in PTSD symptom scores. Although the included studies exhibited moderate to high heterogeneity, the interventions were deemed sufficiently comparable. The presence of closed loops within the network facilitated consistency assessments, confirming the robustness of the findings and indicating no significant inconsistencies across [77].

In conducting an NMA, the potential risk of bias must be considered, particularly regarding outcome assessment blinding and performance bias. Given the nature of the interventions, it is a challenging to achieve complete blinding of participants in most studies, making this a largely unavoidable limitation. PTSD is typically assessed using either self-reported measures or clinician-administered evaluations. Although these two approaches are highly correlated, they may yield differences in the assessment of individual symptoms, overall symptom severity, and diagnostic status [78]. Some scholars have argued that when both self-reported and clinician-rated PTSD symptom scores are available, self-reported scores are generally preferred, as they are considered to more accurately reflect the actual symptoms experienced by children and adolescents with PTSD [79]. Consequently, in psychological and psychosocial intervention trials, self-assessment cannot be blinded, and given that assessors are unlikely to have conflicts of interest in detecting bias, blinded assessments are rarely implemented in such studies.

In many studies, the description of UC interventions is not clearly defined, and the content of UC varies across different studies. Both TUA and NST were included in the UC group. The heterogeneity observed in the analysis is likely attributed, at least in part, to the diversity of routine care provided across studies. The decision to combine the waitlist control group and the no-treatment group was made due to the limited number of studies in the no-treatment group; separating them would not have added substantial value to the analysis. However, it has been suggested that the baseline effects in waitlist control groups may be lower than those in no-treatment groups [80], which could potentially exaggerate the relative effects of active interventions when compared to no-treatment controls. Publication bias and sensitivity analyses indicated no significant evidence of publication

bias, and the robustness of the study findings was confirmed. This suggests that the results remained consistent and unaffected by variations in influencing factors or parameters. Consequently, the conclusions drawn from this study are considered stable and reliable, enhancing the overall credibility of the findings.

During the preliminary literature search phase, a comprehensive array of mind–body therapeutic modalities was explored, encompassing cognitive-behavioral interventions, yoga, positive thinking, meditation, spontaneous training, relaxation therapy, qigong, and tai chi. Existing studies on the treatment of adolescent PTSD predominantly focus on TF-CBT, meditation, CBT, yoga, and mindfulness, with relatively few studies utilising yoga and mindfulness as primary approaches, resulting in limited evidence. Previous research has indicated that mind–body exercises contribute to improvements in both physical and mental health, providing multiple positive effects for individuals with PTSD [81]. Future research should explore a wider range of mind–body interventions to identify more efficient and cost-efficient treatment options. Additionally, combining multiple interventions should be considered in studies. Although the combination of yoga and meditation has not demonstrated significant effectiveness, this may be due to the limited number of existing studies and the underdevelopment of treatment protocols. A multimodal intervention approach could potentially compensate for the limitations of individual treatments, maximising their strengths and offering a more comprehensive therapeutic framework for adolescents with PTSD. Furthermore, current evidence regarding the long-term effectiveness of adolescent PTSD treatments remains scarce, particularly in terms of sustained symptom relief. Future studies should aim to bridge this knowledge gap to enhance our understanding and evaluation of treatment outcomes.

Limitations

Several limitations of this study should be acknowledged. Due to methodological constraints, our analysis focused solely on the overall effectiveness of mind–body therapies that primarily integrate active physical exercises with mindfulness practices, without considering the potential impact of passive mind–body therapies. Moreover, many studies included in the analysis were influenced by additional treatment parameters, such as exercise, dance, and play therapy. Furthermore, in conducting multiple comparisons, it was not possible to control for other potential differences, including gender and age disparities across diverse experimental settings or intervention types. This study offers a thorough evaluation of mind–body therapies for PTSD in adolescents. However, it is important to note that the findings may not be universally applicable to all forms of trauma. For instance, treatments that yield positive results in cases of sexual victimization may not necessarily have the same effect in situations involving natural disasters, and vice versa. Further research is necessary to investigate how distinct types of trauma influence treatment outcomes. These investigations can provide valuable insights and facilitate the development of more targeted and effective treatments.

Furthermore, the scope of future literature inclusion needs to be expanded. Due to the relatively small sample size of patients included in this study and varying quality of the studies, the available direct comparative evidence is limited. As a result, our findings should be interpreted with caution. Future research should revisit these conclusions when a larger body of high-quality studies becomes available. Finally, there appears to be a certain degree of uncertainty within the existing literature. Some of the references cited in this study lack clarity in their risk of bias assessments, which may contribute to a higher risk of bias in the results. To enhance the quality of future research, it is essential to improve the clarity and accuracy of the literature used.

Conclusions

This NMA aimed to compare the effects of various mind–body interventions on adolescents with PTSD. The findings indicate that TF-CBT, meditation, CBT, yoga combined with meditation and mindfulness are all effective in alleviating PTSD symptoms, with TF-CBT demonstrating the highest efficacy. Although yoga combined with meditation and mindfulness interventions have shown promising effects, the limited available evidence underscores the need for further studies to confirm their effectiveness. Overall, the present study corroborates previous research findings and emphasizes the potential of mind–body interventions in the treatment of adolescents PTSD. Future research should focus on conducting more high-quality randomized controlled trials comparing multiple interventions to generate robust evidence on their relative effectiveness. Additionally, long-term follow-up studies are essential to evaluate the sustained clinical and cost-effectiveness of these interventions in real-world settings.

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Authors' contributions
Z.B.J. participated in the conceptualization phase by developing the initial research idea, research questions or hypotheses, and the overall research design. Z.B.J., S.X.Y., Z.J.C. conducted data collection, screening of the literature and literature inclusion. Z.B.J. created graphs and charts and analyzed and interpreted the data. Z.B.J. was responsible for writing and revising the first draft of the manuscript. Y.J. participated in the manuscript's refinement work. All authors approved the final manuscript.

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Data availability
Data is provided within the manuscript or supplementary information files. The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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