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Original Article

Military-related posttraumatic stress disorder and mindfulness meditation: A systematic review and meta-analysis

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ABSTRACT

Purpose: Posttraumatic stress disorder (PTSD) is a significant global mental health concern, especially in the military. This study aims to estimate the efficacy of mindfulness meditation in the treatment of military-related PTSD, by synthesizing evidences from randomized controlled trials.

Methods: Five electronic databases (Pubmed, EBSCO Medline, Embase, PsychINFO and Cochrane Library) were searched for randomized controlled trials focusing on the treatment effect of mindfulness meditation on military-related PTSD. The selection of eligible studies was based on identical inclusion and exclusion criteria. Information about study characteristics, participant characteristics, intervention details, PTSD outcomes, as well as potential adverse effects was extracted from the included studies. Risk of bias of all the included studies was critically assessed using the Cochrane Collaboration's tool. R Statistical software was performed for data analysis.

Results: A total of 1902 records were initially identified and screened. After duplicates removal and title & abstract review, finally, 19 articles in English language with 1326 participants were included through strict inclusion and exclusion criteria. The results revealed that mindfulness meditation had a significantly larger effect on alleviating military-related PTSD symptoms compared with control conditions, such as treatment as usual, present-centered group therapy and PTSD health education (standardized mean difference (SMD) = -0.33; 95% CI [-0.45, -0.21]; $p < 0.0001$). Mindfulness interventions with different control conditions (active or non-active control, SMD = -0.33, 95% CI [-0.46, -0.19]; SMD = -0.49, 95% CI [-0.88, -0.10], respectively), formats of delivery (group-based or individual-based, SMD = -0.30, 95% CI [-0.42, -0.17], SMD = -0.49, 95% CI [-0.90, -0.08], respectively) and intervention durations (short-term or standard duration, SMD = -0.27, 95% CI [-0.46, -0.08], SMD = -0.40, 95% CI [-0.58, -0.21], respectively) were equally effective in improving military-related PTSD symptoms.

Conclusion: Findings from this meta-analysis consolidate the efficacy and feasibility of mindfulness meditation in the treatment of military-related PTSD. Further evidence with higher quality and more rigorous design is needed in the future.

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Introduction

Posttraumatic stress disorder (PTSD) is a severe, chronic and debilitating mental and behavioral disorder following one or more traumatic events, with an estimated lifetime prevalence of approximately 6.8% in general US population.¹ The World Mental Health Survey Consortium revealed that over 70% of general population experienced at least one traumatic event in their lifetime around the world.² It is well-known that both active military personnel and veterans tend to experience various life-threatening traumatic events and be under highly intense stress. As a result, they are at a particularly high risk of developing PTSD, which could be regarded as military-related PTSD.³ The prevalence of military-related PTSD after deployment in Iraq or Afghanistan was reported to be 13.2% in operational infantry units.⁴ The estimated results from the National Vietnam Veterans Longitudinal Study showed that approximately 11% veterans continued to suffer from PTSD symptoms 40 years after the Vietnam War.⁵ Moreover, a review on the prevalence of PTSD in Operation Enduring Freedom/Operation Iraqi Freedom veterans revealed that the PTSD prevalence was as high as 23%.⁶

As the Diagnostic and Statistical Manual of Mental Disorders 5th edition noted, PTSD is characterized by intrusive experience, persistent avoidance, negative alterations in cognitions and mood, as well as marked alterations in arousal and reactivity related to the traumatic events.⁷ In addition, it is universally acknowledged that military-related PTSD is a complicated and heterogeneous health concern accompanied by varying degrees of mental and physical health issues, such as chronic pain, fatigue and depression,^{8–10} which bring about a heavy burden on individuals, families and the army. It was revealed that the most common mental disorders reported by military personnel deployed to combat zones were PTSD and alcohol misuse.¹¹ While alcohol misuse has been found to have a considerably higher prevalence than that reported among general population and might protract the course of PTSD.¹² Furthermore, it is noted that the service members with mental disorders, especially PTSD, may experience a strong sense of stigma, specifically concerns about how their fellows and military leadership will judge them, which keeps them from seeking professional medical help.¹³ Given that military-related PTSD has a detrimental impact on the combat effectiveness of the army,¹¹ valid measures should be employed to address this issue.

Currently, multifarious psychological and pharmacological interventions have been applied for PTSD. The effect of psychotherapies has been extensively evaluated, which can be broadly grouped into “trauma-focused” and “non-trauma-focused”. The most recent recommendations in the Department of Veterans Affairs (VA)/Department of Defense (DoD) Clinical Practice Guideline for the Management of Posttraumatic Stress Disorder list individual trauma-focused psychotherapies as the first-line treatment.¹⁴ According to the guideline, prolonged exposure,^{15,16} cognitive processing therapy,¹⁷ and eye movement desensitization and reprocessing¹⁸ possess the strongest evidence derived from clinical trials. With regard to non-trauma-focused psychotherapies, the evidence-based treatment options include stress inoculation training, present-centered therapy, and interpersonal psychotherapy.^{19,20} The pharmacotherapies are also widely used in PTSD treatment.²¹ Three selective serotonin reuptake inhibitors (Sertraline, Paroxetine and Fluoxetine) and one serotonin norepinephrine reuptake inhibitor (Venlafaxine) are recommended as monotherapy for the management of PTSD with relatively sufficient evidence.^{22–24} Despite empirical support for the above therapies, both psychotherapies and pharmacotherapies are restricted to some limitations. Studies on trauma-focused psychotherapies for PTSD have reported high rates of dropout and nonresponse, and

many patients may suffer from residual symptoms after treatment.^{3,25} The average rate of dropout from psychotherapies for military-related PTSD among combat veterans was estimated to be 36%.²⁶ Results from a meta-analysis showed that nearly 27% of patients reduced the dose or withdrew from medication without following prescription because they were concerned about unremarkable curative effect or potential adverse effects, such as sexual dysfunction, increased sweating, and sleep disorders.²⁷ Therefore, more effective and better tolerated PTSD treatment options are desired.

There is growing evidence showing that complementary and alternative medicine (CAM), especially mind-body therapies, is expected to be effective and viable interventions for PTSD management under the military context.^{28–30} Reviews on CAM for PTSD also provided support for the treatment effect of these interventions on PTSD symptoms.^{31,32} Notably, it was put forward that an acute increase in distress during the treatment period could contribute to the high rate of dropout and nonresponse among patients receiving trauma-focused psychotherapies,³³ and CAM might be effective in addressing this problem by regulating physiological and psychological arousal.³⁴

Of various CAM practices, meditation has been extensively researched and reported to be the most widely accepted. Meditation is a mind-body technique referring to a wide range of emotional and attentional regulatory strategies that contributes to happiness cultivation and emotion management.³⁵ There are diverse forms of meditation practices, such as mindfulness meditation, mantra meditation, etc. Rooted in Eastern Buddhist, mindfulness has sprung up in Western as a popularizing healthy lifestyle in recent years. Kabat-Zinn³⁶ described mindfulness as an intentionally focused attention on the moment-to-moment experience in a state of non-judgmental awareness. Generally, mindfulness refers to a state of consciousness sustaining one's attention on the experience occurring in the present moment, and is often reached by various meditation practices.³⁷ Mindfulness meditation involves a variety of meditation techniques with a focus on mindfulness. One of the most popular and well-researched mindfulness meditation programs is mindfulness-based stress reduction (MBSR), an 8-week group course that teaches practitioners to non-judgmentally experience the present moment,³⁸ which has been well-documented to improve stress-related symptoms, such as depression, anxiety and PTSD.^{39,40} Moreover, mindfulness-based cognitive therapy,⁴¹ an integration of MBSR and cognitive-behavior therapy, has also been applied to PTSD treatment.⁴² Regarding military-related PTSD, it has been proposed that the high levels of guilt and shame among veterans can prevent them from seeking medical care and result in early withdrawal from treatment.⁴³ Accordingly, taking mindfulness meditation as the treatment of military-related PTSD may improve the acceptance and tolerance in military PTSD patients and reduce possible negative mood, including guilt and shame.

Meta-analyses of the impact of meditation practice on PTSD have shown significant evidence of encouraging treatment effects.^{44–46} For example, 18 studies were included in Hopwood and Schutte's study,⁴⁴ where mindfulness meditation was demonstrated to be effective in relieving PTSD symptoms compared with control conditions, with a Hedges's g of -0.44 . However, to our knowledge, systematic reviews or meta-analyses specifically aiming at meditation training for PTSD among veterans and active military personnel are limited in number. Therefore, an emphasis was put on mindfulness meditation for the treatment of military-related PTSD in this study, with a specific focus on randomized controlled trials (RCTs), to estimate the treatment effect of this kind of intervention on military-related PTSD symptoms. Besides, it was found that mindfulness meditation training

was brought to the military by Johnson et al. in 2011^{47,48} and received increasingly attention during the past decade. As a result, relative studies published within the past decade were examined in this study.

The primary purpose of this meta-analysis was to test the hypothesis that mindfulness meditation would have advantages over control conditions in alleviating the severity of military-related PTSD symptoms. Furthermore, additional factors influencing the treatment effect were investigated, including control condition (active or non-active control), format of interventions delivered (group-based or individual-based) and intervention duration (short-term or standard duration).

Methods

This review was carried on in accordance with the guidelines in the Preferred Reporting Items for Systematic Reviews and Meta-analyses statement.⁴⁹ And the protocol of the review was registered in the International Prospective Register of Systematic Reviews (registration number CRD42020188543).

Search strategy

Studies were identified through a comprehensive computerized search of PubMed, EBSCO Medline, Embase, PsychINFO and Cochrane Library between January 2010 and December 2019. Three major ways of searching were used, including the medical subject headings (MeSH) search, text word search and Boolean calculation search. For example, the searching keywords in the Pubmed were: [(PTSD OR posttraumatic stress disorder OR post-traumatic stress disorder OR posttraumatic stress) OR (“Stress Disorders, Post-Traumatic”) [MeSH]] AND (meditation OR mindful OR mindfulness OR yoga). Also, additional studies were acquired by searching the reference lists of relevant articles, especially reviews or meta-analysis on meditation and PTSD.

Inclusion and exclusion criteria

The inclusion criteria for this meta-analysis were studies: (1) specifically focusing on active military personnel or veterans with military-related PTSD, (2) employing meditation-based therapies as main interventions, (3) RCTs with any comparator as a control, (4) use of a clinician or self-report PTSD measure, (5) sufficient reporting of statistics of PTSD symptom severity (mean and SD) to calculate an effect size for meta-analysis, and (6) available in English language literature.

Articles were excluded on any of the following grounds: (1) article type of commentaries, editorials, letters, reviews or case reports, (2) meditation not as a primary intervention component, (3) no random assignment, (4) no use of PTSD measure, (5) not military-related PTSD, (6) unavailable of full-text articles, and (7) no sufficient statistical results even if emails were send to the corresponding authors.

Data extraction and coding

After the duplicated records were removed by EndNote, two authors independently screened the remaining records by reviewing the titles and abstracts, in order to minimize errors and potential bias. Then, full-text articles were retrieved and assessed for eligibility with identical inclusion and exclusion criteria. Furthermore, the two authors performed data extraction consecutively based on a pre-designed data collection form. The first

author extracted and coded all the studies; then, the second author checked the extracted information. Disagreements were resolved by discussion between the two sides or arbitration from a third author, and consensus was reached for all the included studies.

The following information was extracted from each eligible study: study characteristics (author, publication year, study design, control condition), participant characteristics (sample size, gender, age), intervention details (means of intervention, intervention frequency and duration, the format of intervention delivery), PTSD outcomes (primary measure, PTSD symptom outcomes, follow-up time), as well as potential adverse effects.

Quality assessment

The Cochrane Collaboration's tool was used to assess the risk of bias for all the included studies.⁵⁰ We assessed each study on the following domains: random sequence generation, allocation concealment (selection bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective reporting (reporting bias), and other sources of bias. However, blinding of participants and personnel (performance bias) was not assessed in this study, since it was not likely to make the participants be blind to the therapy that they received in most behavioral intervention researches. Every domain was judged as 'low risk', 'unclear risk', or 'high risk' of bias (Appendix 1).

Data analysis

Considering that PTSD outcomes were continuous data and the included studies might report the same outcome with different measures, standardized mean difference (SMD) was used to measure the effect size, together with 95% CI, so as to make comparisons across studies and to combine results in a meta-analysis. A negative value indicates lower severity of PTSD symptoms in the experimental group compared with the control group, as well as a larger effect of the intervention. According to Cohen's suggestion, the value of the effect size SMD can be rated as follows: 0.2 represents a small effect, 0.5 a medium effect, and 0.8 a large effect.⁵¹ A two-tailed *p* value less than 0.05 was considered statistically significant.

The heterogeneity between studies was evaluated with *Q* statistical test. A significant *p* value (usually *p* < 0.1) or a large *Q* statistic with *k*-1 degree of freedom (*k* = the number of studies) suggests there existing heterogeneity between studies. However, this test has poor power when the number of included studies is limited or the sample size is small. Therefore, *I*² statistic was also used, which quantifies the effect of heterogeneity across studies ranging from 0% to 100%. The threshold of 25%, 50%, 75% in *I*² test indicated a low, moderate and high degree of heterogeneity, respectively.⁵² A fixed-effect model is adaptive when there is no specific statistical heterogeneity among studies in a meta-analysis. Otherwise, a random-effects model is best when there is heterogeneity that cannot readily be explained. Given the studies included in the current analysis were expected to be heterogenous, a random-effects model was adopted. Subgroup analyses and sensitivity analysis were also conducted to further detect the sources of heterogeneity. Subgroup analyses were based on control condition, delivery of intervention and intervention duration. Additionally, publication bias was detected and evaluated using funnel plots and Egger's tests.⁵³ All statistical computing was performed in R software using the meta statistical package.⁵⁴

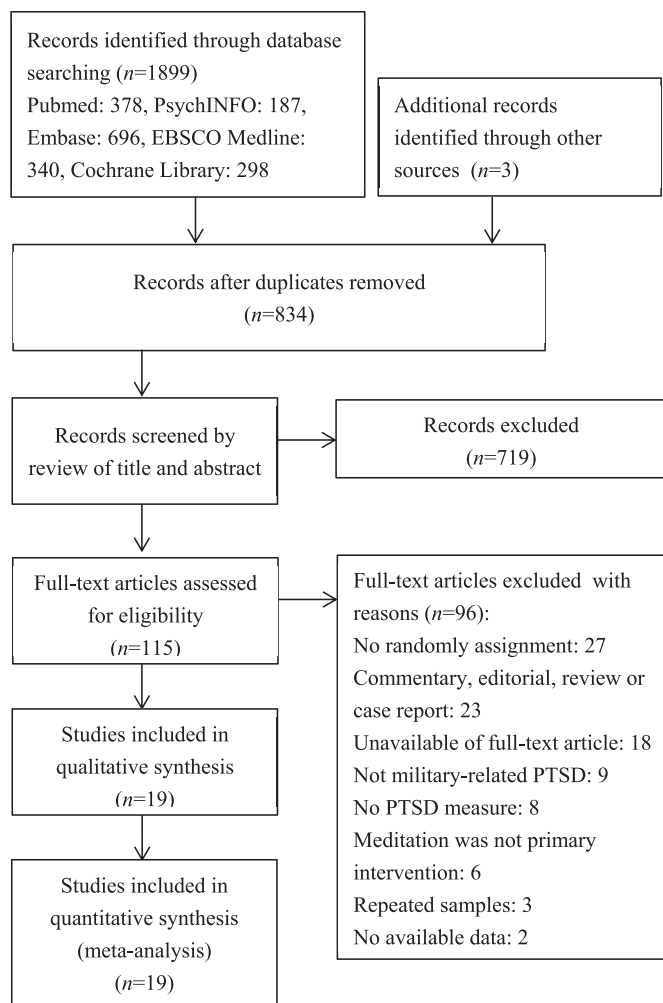


Fig. 1. Flow diagram of study selection process.

Results

As illustrated in Fig. 1, a total of 1902 records were initially identified and screened and finally 19 studies were included. Of the 19 studies, two used a multiple-arm design (more than one intervention groups with a common control group).^{55,56} According to the recommended method from the Cochrane handbook, data from all relevant intervention groups of the study were merged into a single group.⁵⁷ Therefore, the final analyses were on the basis of 19 RCTs with a total sample size of 1326 participants.

Study characteristics

Table 1 provides a summary of the characteristics of all the included studies. The sample size from individual study varied greatly from 15 to 191. Of the 1326 participants, the majority were male (median = 88%), and the mean age ranged from 28.6 to 58.5 years (median = 49.9 years). Though this study primarily laid stress on mindfulness meditation, the specific meditation programs employed in the included studies varied. Among the 19 studies examined, seven assessed MBSR, one of which was brief mindfulness training with four-week courses^{30,40,58–62}; one assessed mindfulness meditation, and participants mainly practiced body scanning⁵⁵; two assessed mind-body bridging, a novel mind-body intervention, which aimed to help practitioners calm and relax, and bring them into a state of balance and harmony^{63,64}; two

assessed mantram repetition program, a program that taught participants to train attention and regulate emotion through practicing certain techniques^{65,66}; one assessed transcendental meditation, which turned one's attention to inward to experience the source of thought⁵⁶; one assessed compassion meditation, which helped practitioners cultivate a sense of common humanity and engender the heartfelt wish that the self and others free from miserableness⁶⁷; two assessed Sudarshan Kriya yoga, a breathing-based meditation^{68,69}; one assessed Kripalu yoga, which was consisted of physical postures, breathing and meditation, with an emphasis on moving meditation.⁷⁰ One assessed mindfulness-based exposure therapy, which incorporated mindfulness training and exposure therapy.⁷¹ One assessed integrative exercises, a combination of aerobic exercise, strength training and yoga on the ground of mindfulness principles.⁷² Despite this, all the interventions employed meditation practice in the programs. We provided a summary of the relevant meditation programs with brief descriptions originally extracted from the included studies (Appendix 2).

Among the included studies, four were waitlist control conditions without any treatment, which were considered as non-active control; the remaining ($k = 15$) employed an active control condition, including treatment as usual, present-centered group therapy and PTSD health education. Majority of the interventions ($k = 16$) were done in groups, while only three were delivered through individual to individual. Most interventions were delivered once a week, and the intervention duration ranged from five days to 12 weeks. In view of the manualized program—MBSR—is comprised of 8-week courses, we categorized included RCTs whose intervention duration was eight weeks or longer as standard duration ($k = 12$), and intervention duration shorter than eight weeks as short-term duration ($k = 7$). Of the 19 RCTs, most ($k = 12$) used the Clinician Administered PTSD Scale⁷³ as the primary measure of PTSD symptoms, followed by the Posttraumatic Stress Disorder Checklist ($k = 7$),⁷⁴ and the remaining one used PTSD Symptom Scale Interview.⁷⁵ Fourteen studies performed follow-up assessment apart from post-intervention assessment, and the longest follow-up time was one year.

Regarding the potential adverse events, seven of the 19 included studies reported that no intervention-related adverse events occurred during the study period, while more than half ($k = 10$) studies failed to mention about adverse events. Two studies reported the presence of adverse events during the intervention. One study employing Sudarshan Kriya yoga reported that transient mild psychological ailment emerged with fleeting images about the past terrible memory among some participants while they were practicing yoga breathing.⁶⁸ However, it was pointed out that such reaction was expected for the reason that re-experiencing symptoms were closely associated with PTSD. Besides, participants' reactions were alleviated by slow breath practices. Another study⁷⁶ reported that two patients respectively from the intervention group and the control group were admitted to the inpatient psychiatry unit due to worsening PTSD symptoms. It was also stressed that no participants withdrew from the MBSR intervention due to worsening PTSD symptoms or any troubles resulted from the intervention, which meant that the admission for inpatient psychiatry treatment was not directly caused by the MBSR intervention.

Effect of mindfulness meditation on military-related PTSD symptoms

To verify the hypothesis that mindfulness meditation has an advantage of improving military-related PTSD symptoms, an overall effect size was calculated for all the included studies. Fig. 2 is the forest plot for PTSD treatment effects, with effect sizes for each study. No significant heterogeneity was found among the studies (Q

Table 1
Study characteristics of the included studies.

Study	Intervention	Intervention frequency; duration	Control condition	Sample size (Male, %)	Age (years), mean (SD)	Primary measure	Follow-up assessment (postbaseline)	Adverse events
Bormann et al. ⁶⁵ 2013	MRP + TAU, group-based	6 sessions, 1.5 h; 1 time/week	TAU	146 (97)	57 (10.10)	CAPS	6-week (post-intervention)	No
Bormann et al. ⁶⁶ 2018	MRP, individual-based	8 sessions, 1 h; 1 time/week	PCGT	173 (85)	48.9 (14.54)	CAPS	2-month	Not mentioned
Bremner et al. ⁵⁸ 2017	MBSR, group-based	9 sessions, 2.5 h; 1 time/week+ a 6-h retreat	PCGT	17 (100)	34.5 (8.28)	CAPS	6-month	Not mentioned
Carter et al. ⁶⁸ 2013	SKY, group-based	22 h, 5 days;	WLC	25 (100)	58.5 (4.17)	CAPS	6-month	Yes
Davis et al. ⁶² 2018	MBSR, group-based	9 sessions, 1.5 h; 1 time/week+ a 6-h retreat	PCGT	191 (81)	51.4 (11.13)	CAPS	16-week	No
Goldstein et al. ⁷² 2018	Integrative exercise, group-based	36 sessions, 1 h; 3 times/week	WLC	47 (81)	46.8 (14.93)	CAPS	12-week (post-intervention)	Not mentioned
Kearney et al. ⁷⁶ 2012	MBSR + TAU, group-based	9 sessions, 2.5 h; 1 time/week+ a 7-h retreat	TAU	47 (79)	52 (12.50)	PCL	4-month	Yes
Kearney et al. ⁴⁰ 2016	MBSR + TAU, group-based	9 sessions, 2.5 h; 1 time/week+ a 7-h retreat	TAU	55 (85)	49.9 (7.19)	PSSI	6-month	Not mentioned
King et al. ⁷¹ 2016	MBET, group-based	16 sessions, 2 h; 1 time/week	PCGT	23 (100)	32.1 (8.43)	CAPS	16-week	Not mentioned
Lang et al. ⁶⁷ 2019	CM, group-based	10 sessions, 1.5 h; 1 time/week	Veteran.calm	28 (75)	49.1 (14.5)	CAPS	10-week (post-intervention)	No
Nakamura et al. ⁶⁴ 2011	MBB, group-based	2 sessions, 1.5 h; 1 time/week	Sleep hygiene (1 h/week)	63 (95)	52.1 (10.46)	PCL	2-week (post-intervention)	Not mentioned
Nakamura et al. ⁶³ 2017	MBB, group-based	3 sessions, 3 h; 1 time/week	Sleep hygiene Education	60 (90)	50.7 (7.3)	PCL	3-month	Not mentioned
Nidich et al. ⁵⁶ 2018	TM, group-based	12 sessions, 1.5 h; 1 time/week	PTSD health education	134 (84)	46.3 (15.31)	CAPS	6-month	No
Niles et al. ⁶⁰ 2012	MBSR, individual-based	8 sessions; 2 in-person sessions (45 min) +6 weekly telephone sessions (20 min)	Telehealth psychoeducation	27 (100)	52 (13)	CAPS	6-week	No
Polusny et al. ³⁰ 2015	MBSR, group-based	9 sessions, 2.5 h; 1 time/week+ a 6.5-h retreat	PCGT	116 (84)	58.5 (9.8)	PCL	2-month	No
Possemato et al. ⁶¹ 2016	Primary care brief mindfulness training, group-based	4 sessions, 1.5 h; 1 time/week	PC-TAU	62 (87)	46.4 (16.3)	CAPS	8-week	No
Reinhardt et al. ⁷⁰ 2017	Kripalu yoga, group-based	20 sessions, 1.5 h; 2 times/week	WLC	15 (88)	47.8 (13.77)	CAPS	22-week	Not mentioned
Seppälä et al. ⁶⁹ 2014	SKY, group-based	7 sessions, 3 h; 1 time/day	WLC	20 (100)	28.6 (4.95)	PCL	1-year	Not mentioned
Wahbeh et al. ⁵⁵ 2016	Mindfulness meditation, individual-based	6 sessions, 20 min; 1 time/week	Sitting quietly	77 (95)	52.1 (12.34)	PCL	6-week (post-intervention)	Not mentioned

CAPS: clinician Administered PTSD Scale; CM: compassion meditation; MBB: mind-body bridging; MBET: mindfulness-based exposure therapy; MBSR: mindfulness-based stress reduction; MRP: mantram repetition program; PCGT: present-centered group therapy; PCL: PTSD Checklist; PC-TAU: primary care treatment as usual; PSSI: PTSD Symptom Scale Interview; PTSD: posttraumatic stress disorder; SKY: Sudarshan Kriya yoga; TAU: treatment as usual; TM: transcendental meditation; WLC: waitlist control.

(df 18) = 20, $I^2 = 10\%$, $p = 0.33$). Overall, the meta-analysis with a random effects model yielded a statistically significant effect size in a small to medium range (SMD = -0.33, 95% CI [-0.45, -0.21], $p < 0.0001$), indicating that mindfulness meditation had a significantly therapeutic effect on ameliorating military-related PTSD symptoms compared with control conditions across all the studies.

Subgroup analysis

Figs. 3–5 display the results of subgroup analyses. The effect size for studies employing an active control was similar to the overall effect size and remained statistically significant (SMD = -0.33, 95% CI [-0.46, -0.19]), with no significant heterogeneity (Q (df 14) = 18.31, $I^2 = 24\%$, $p = 0.19$). The studies employing a non-active control also had a significant effect size (SMD = -0.49, 95% CI [-0.88, -0.10]), with no significant heterogeneity (Q (df 3) = 0.94,

$I^2 = 0\%$, $p = 0.81$). Effects did not differ between active control and non-active control (Q = 0.59, $p = 0.44$) (Fig. 3).

No matter delivered by group (SMD = -0.30, 95% CI [-0.42, -0.17]) or by individual (SMD = -0.49, 95% CI [-0.90, -0.08]), the effect sizes were both significant. No significant heterogeneity existed among the group-based studies (Q (df 15) = 15.09, $I^2 = 1\%$, $p = 0.44$) or the individual-based studies (Q (df 2) = 4.13, $I^2 = 52\%$, $p = 0.13$). Effects did not differ between group-based studies and individual-based studies (Q = 0.77, $p = 0.38$) (Fig. 4).

Both interventions with a standard duration (SMD = -0.40, 95% CI [-0.58, -0.21]) and a short-term duration (SMD = -0.27, 95% CI [-0.46, -0.08]) had significant effect sizes. No significant heterogeneity was found among the standard duration studies (Q (df 11) = 16.81, $I^2 = 35\%$, $p = 0.11$) or the short-term duration studies (Q (df 6) = 2.76, $I^2 = 0\%$, $p = 0.84$). Effects did not differ between

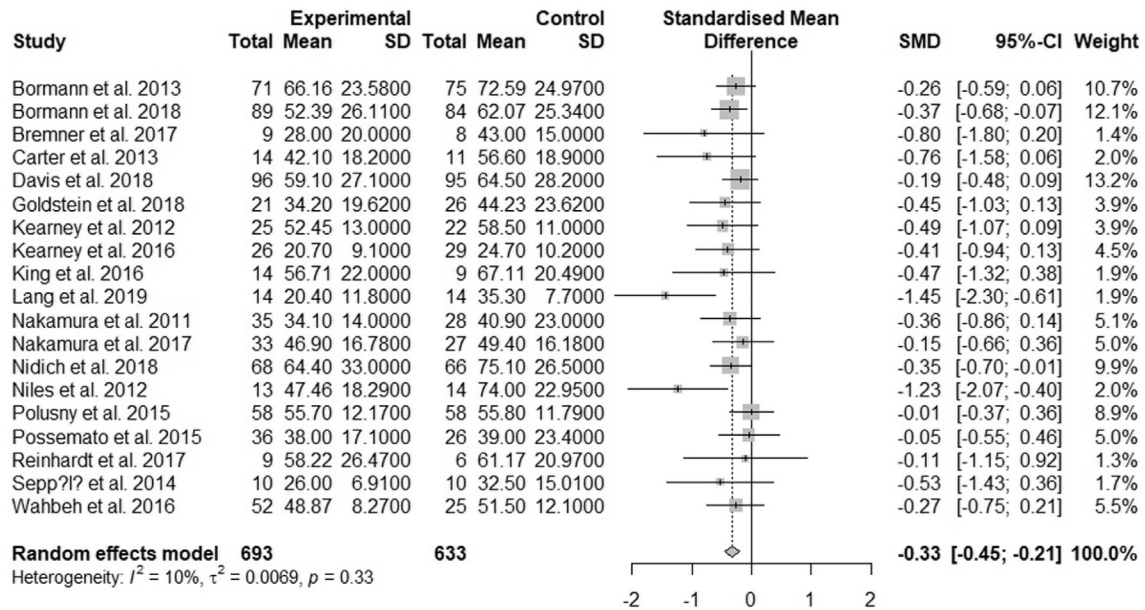


Fig. 2. Forest plot for PTSD post treatment effects (mindfulness meditation interventions vs. control conditions). Negative values indicate fewer PTSD symptoms in the experimental condition than the control condition. PTSD: posttraumatic stress disorder.

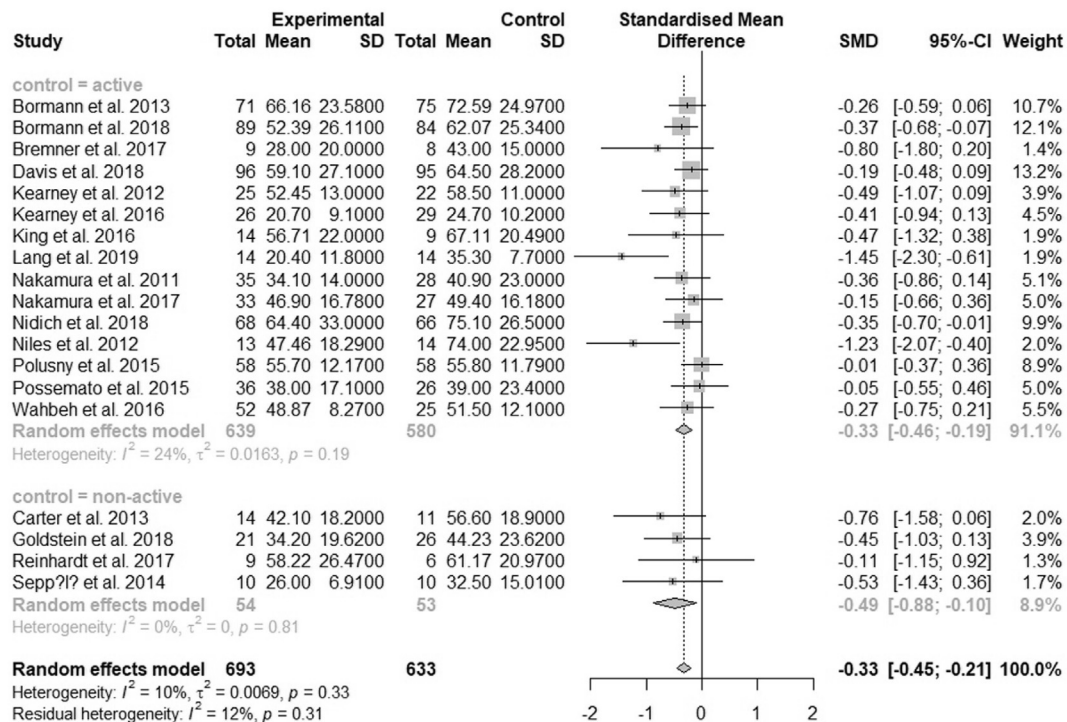


Fig. 3. Subgroup analysis for PTSD treatment effect by control condition. PTSD: posttraumatic stress disorder.

interventions with a standard duration and a short-term duration ($Q = 0.90$, $p = 0.34$) (Fig. 5).

Sensitivity analysis

Sensitivity analysis was performed by omitting each single study at one time to determine the influence of each study on the overall effect size. The results revealed that the overall effect size

was not extremely influenced, with the effect sizes for each study ranging from $SMD = -0.35$ to -0.30 , suggesting the reliability and stability of the results from the current meta-analysis.

Publication bias

The funnel plot was visually asymmetrical and Egger's test showed that there might be publication bias ($p = 0.01$). Duval and

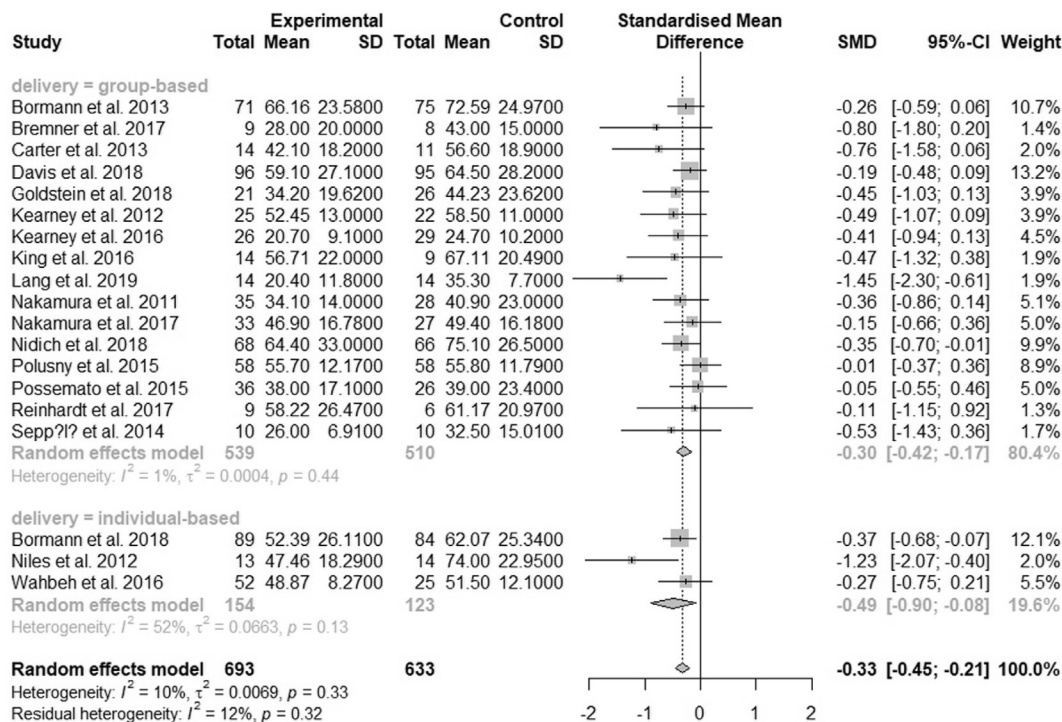


Fig. 4. Subgroup analysis for PTSD treatment effect by format of intervention delivery. PTSD: posttraumatic stress disorder.

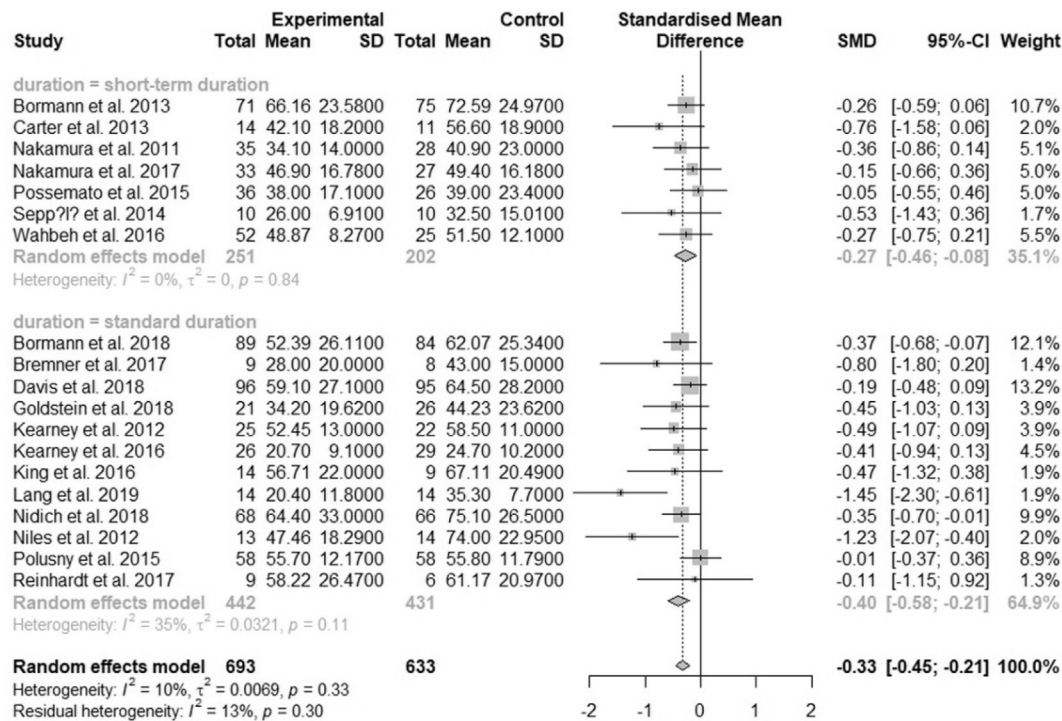


Fig. 5. Subgroup analysis for PTSD treatment effect by intervention duration. PTSD: posttraumatic stress disorder.

Tweedie’s “trim and fill” method⁷⁷ was used to adjust the funnel plot asymmetry. Five potentially missing studies were added, and the results yielded a significant effect size (SMD = -0.27, 95% CI [-0.42, -0.13], $p = 0.0002$).

Discussion

A total of 1326 participants were included in this meta-analysis, focusing on military-related PTSD and mindfulness meditation. The

results manifested that mindfulness meditation significantly alleviated the severity of military-related PTSD symptoms compared with control conditions. The overall effect size was $SMD = -0.33$, indicating that mindfulness meditation had a significant effect on ameliorating military-related PTSD symptoms in a small to medium range. There was no significant heterogeneity among the included studies ($Q(df\ 18) = 20, I^2 = 10\%, p = 0.33$), which further supported the general effectiveness of mindfulness meditation on military-related PTSD. Nevertheless, such results should be interpreted with caution since varied meditation programs, sample size, intervention conditions and other factors may affect the treatment effect among included studies. Additionally, no obvious differences were found between studies with different control conditions, formats of intervention delivery, or intervention duration, suggesting that interventions with active or non-active control, delivered by group or individual and with short-term or standard duration were equally effective in improving military-related PTSD symptoms.

The present results were partly in consistent with previously published meta-analyses on similar meditation programs. For instance, Gallegos et al.⁷⁸ found that meditation and yoga were effective in the improvement of PTSD symptoms among adults ($SMD = -0.39, 95\% CI [-0.57, -0.22], p < 0.001, k = 19$). In this meta-analysis, interventions were grouped into three categories based on how the meditative practices engaged one's attention: mindfulness meditation, other meditation, and yoga movement. The results suggested that no considerable differences existed among intervention types. However, in another systematic review⁴⁶ that investigated the efficacy of meditation interventions on PTSD symptoms, depression, anxiety, quality of life, functional status, and adverse events in adults diagnosed with PTSD, it was revealed that meditation appeared to improve PTSD ($SMD = -0.41; 95\% CI [-0.81, -0.01]; k = 8$) and depression symptoms ($SMD = -0.34; 95\% CI [-0.59, -0.08]; k = 8$) significantly. Nevertheless, there was no substantial statistical evidence to support the treatment effect of meditation on anxiety or quality of life, and no functional status or adverse events were reported in the included studies. It is worth noting that, in most published studies, meditation programs were compared with waitlist control, treatment as usual, psychoeducation, present-centered group therapy, etc. Nearly none of studies directly compare meditation with first-line trauma-focused psychotherapies. Just as among the current meta-analysis, only one study employed prolonged exposure, the "gold standard" treatment for PTSD, as one of the intervention conditions. And the results of this study demonstrated that transcendental meditation was non-inferior to prolonged exposure on relieving PTSD symptoms.⁵⁶ Research is needed to further determine the treatment conditions between non-trauma-focused CAM practices and evidence-based trauma-focused psychotherapies or pharmacotherapies in the improvement of PTSD symptoms.

There was no significant difference between studies employing active or non-active control in improving PTSD symptoms. However, the study employing compassion meditation, which was adapted specially for veterans, had the largest effect size compared with "veteran. calm"—a "mind-body intervention" with a focus on relaxation. This observation did not correspond with the previous finding that studies comparing mindfulness meditation with waitlist control conditions had the largest effect size and studies comparing mindfulness meditation with an active PTSD treatment (cognitive-behavior therapy) had the smallest effect size.⁴⁴ It might enlighten the development of the specialized treatment for military-related PTSD. No matter delivered by group or by individual, meditation practices had a significant effect on PTSD symptoms, which could be considered as a prominent advantage in practical application, especially in the military context. In addition,

it was found that interventions with short-term duration and standard duration were equally effective in improving PTSD symptoms. However, it should be mentioned that the intervention duration in this review merely referred to the total timespan interventions lasted which might lead to this result, while the precise intervention duration of each study was not calculated. A previous study suggested that meditation with a longer duration was associated with greater improvement in PTSD symptoms.⁴⁴

In relation to adverse effects, in the studies included in this meta-analysis, some reported no intervention-related adverse effects or the adverse effects were uncommon and mild, while many did not involve the assessment of adverse effects. However, a recent review on the prevalence of adverse events in meditation showed that the total prevalence was 8.3%, and the most reported were anxiety and depression.⁷⁹ Moreover, it was demonstrated that meditation training might aggravate the severity of PTSD symptoms under some circumstances,⁸⁰ which should be taken into serious consideration for both therapists and practitioners when using meditation practices to improve PTSD or other mental disorders.

Several limitations must be considered in light of the current findings. First, the attrition rate was not estimated though majority of the studies reported completion rates. The existing of diverse definitions of completion across studies was the main cause. For instance, some studies defined completion as attending four or more sessions, while some defined completion as attending all sessions. Second, the severity of PTSD symptoms was the only outcome estimated in the current study. To our knowledge, veterans with PTSD tend to be comorbid with other mental disorders (such as depression and sleep disorders) and get impairments in social functioning (such as terrible relationships with families and high possibility of unemployment).^{81,82} It is demonstrated that mindfulness meditation is a promising intervention that is applicable to a wide range of psychological disorders, such as depression, anxiety, chronic pain, and substance abuse,⁸³ which further provides evidence for potential benefits of the intervention. Third, existing studies suggested that the increases in mindfulness were associated with reduction in PTSD symptoms. However, the increase in mindfulness post treatment were not estimated in this study for the reason that there were only a part of studies addressing mindfulness. Finally, some included studies were rated as high or unclear risk of bias, which meant the evidence for the results of this meta-analysis might be underpowered and caution must be taken when interpreting the results.

Despite the limitations outlined above, the meta-analysis succeeded in identifying that mindfulness meditation might be an effective and feasible alternative to treat military-related PTSD. The current meta-analysis focused on the military personnel, among which the prevalence of PTSD was higher than general population. Additionally, one important finding of this review was that a variety of existing studies on meditation programs for PTSD are of poor quality. Take the process of randomization assignment for example, many studies reported inadequately about the generation of random sequences. Future RCTs with high quality and rigorous design are needed to further determine the effectiveness and viability of meditation programs in the treatment of PTSD.

In conclusion, findings from this meta-analysis consolidated the efficacy and feasibility of mindfulness meditation in the treatment of military-related PTSD. Mindfulness meditation had a significant effect on alleviating PTSD symptoms compared with both active and non-active control conditions. Importantly, it is noteworthy that meditation practices do have several advantages in treating PTSD among military personnel. For instance, most training

techniques are easy to master, and can be implemented in routine practice. Moreover, there is no necessity of a licensed medical worker to deliver relevant courses and an experienced therapist or practitioner can guide the whole process, which may expand the use of these interventions in army.

Despite encouraging attention has been paid to mindfulness meditation, future research with higher quality and more rigorous design as well as standardization of training programs⁸⁴ is required to provide evidence for the efficacy of this kind of therapies on PTSD and other mental disorders, such as depression, anxiety, and sleep disorders. Furthermore, the combination of mindfulness meditation with existing evidence-based therapies is needed to develop more options for the management of various mental disorders, which may contribute to individualized treatment for different patients.

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Ethical statement

This study was carried on in accordance with the guidelines in the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. And the protocol of the review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (registration number CRD42020188543).

Declaration of competing interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cjtee.2021.05.003>.

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