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Physical exercise as treatment for PTSD: a systematic review and meta-analysis

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Structured summary

Introduction:

Posttraumatic stress disorder (PTSD) is a cluster of physical and psychiatric symptoms following military or civilian trauma. The effect of exercise on PTSD symptoms has previously been investigated in several studies. However, it has not been fully determined what type of exercise most impacts PTSD symptoms. The aim of the present study was to systematically review the effects of different types of exercise on PTSD symptom severity, and symptoms of coexisting conditions in adults.

Materials and methods:

Electronic searches were conducted in the databases PubMed, APA PsycInfo and SportDiscus, from database inception up until Feb 1, 2021. Inclusion criteria were randomised controlled trials published in English, participants having a PTSD diagnosis or clinically relevant symptoms, and participants randomly allocated to either a non-exercising control group or an exercise group. Data concerning number of participants, age, exercise type and duration, PTSD symptom severity (primary outcome), and symptoms of coexisting conditions (secondary outcomes) were extracted. The subgroup analysis included high or low training dose, military trauma versus non-military traumas, type of intervention (yoga versus other exercise), active or passive control condition, group training versus individual exercise, and study quality. Study quality and risk of bias was assessed using the Grading of Recommendation Assessment, Development and Evaluation (GRADE) guidelines. Meta-analysis was performed with a mixed-effects model and restricted maximum likelihood (ReML) as model estimator, and effect size (ES) was calculated as the standardised difference in mean and 95% CI.

Results:

Eleven studies were included in the present review. Results showed a main random effect of exercise intervention (0.46; 95% CI: 0.18 to 0.74), and a borderline significant interaction between more voluminous (>20 hours in total) and less voluminous (≤20 hours in total) exercise interventions ($p = 0.07$). No significant findings from the subgroup analysis were reported. The secondary outcome analysis showed a small but significant effect of exercise on depressive symptoms (0.20, 95% CI: 0.01 to 0.38), and a larger effect on sleep (0.51, 95% CI: 0.29 to 0.73). For substance use (alcohol and drugs combined) and quality of life, we found significant effects of 0.52 (95% CI: 0.06 to 0.98) and 0.51 (95% CI: 0.34 to 0.69), respectively. No significant effect was found for anxiety (0.18, 95% CI: -0.15 to 0.51), and no sign of publication bias was found.

Conclusions: Exercise can be an effective addition to PTSD treatment, and greater amounts of exercise may provide more benefits. However, as there were no differences found between exercise type, possibly due to the inclusion of a low number of studies using different methodologies, further research should aim to investigate the optimal type, dose, and duration of activity that is most beneficial to persons with PTSD.

Introduction

Individuals exposed to complex trauma, natural disasters, or different types of military trauma are at risk for posttraumatic stress disorder (PTSD). The lifetime prevalence of PTSD in the general American population is around 7-8%,[1, 2] but 2-3 times higher in active duty U.S. military service members.[3-7] The estimates for lifetime PTSD prevalence in European countries are significantly lower than in the U.S.[8, 9] The symptoms of PTSD include re-experiencing or dissociative reactions (*e.g.*, flashbacks), heightened levels of arousal, or negative changes in cognition associated with the traumatic event. Several physical and psychiatric conditions can co-occur with PTSD, such as depression[10, 11] anxiety, sleep disorders, chronic pain, obesity and metabolic syndrome.[12-15] There are also long-term neurological and health changes associated with PTSD[16-19] such as hypothalamic-pituitary-adrenal (HPA) axis dysfunction,[20] impaired physical function,[21-23] and enhanced risk of early functional aging.[24]

During the past decade, the effect of exercise on the symptoms of PTSD in both civilians and veterans has been investigated in several systematic reviews, showing conflicting results.[25-29] However, it has been reported that aerobic exercise and physical activity in general may have positive effects on both primary PTSD symptoms[25-28] and the accompanying health conditions associated with the disorder.[25] While not specifically investigating individuals meeting the criteria for PTSD, different types of exercise as a treatment of PTSD-related mental disorders, such as depression,[30-34] non-apnea sleep disturbances[35] and anxiety,[36] has been evaluated in several studies. For these conditions, several interesting biomarkers have been identified.[37-40]

Yoga is one of the exercise types that has shown promising effects on several mental illnesses,[41, 42] and may produce greater reductions in depressive symptoms than waitlist, treatment as usual and attention control, with a possible dose-response effect.[43] However, intervention studies involving yoga for PTSD patients have presented inconsistent findings.[29, 44-46] For example, one study found greater benefits of yoga compared to walking and health education[45] while another study showed marginally significant to no effects on PTSD and depression outcomes in women.[29] Therefore, due to the low number of high quality studies and uncertain clinical effects, there are currently no recommendations on implementing any type exercise in the standard treatment of PTSD.

The aim of the present study was to systematically review randomised, controlled trials for the effects of exercise on PTSD symptom severity, either in persons with diagnosed PTSD, or persons demonstrating clinically significant PTSD symptoms. Secondary aims were to determine the impact of exercise on depressive symptoms, anxiety, sleep behaviour, substance abuse and dissociative symptoms. The hypotheses were that exercise would generate beneficial effects on symptom severity in persons with PTSD; and that a) low intensity activity (yoga) would be more favourable than high intensity activities, and b) group activities would be more favourable than individual activities.

Methods

This study systematically reviewed and performed a meta-analysis on original, peer-reviewed randomised controlled trials (RCTs) examining the effects of exercise on PTSD symptom severity. For the purpose of this review, exercise was defined as "physical activity that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness".[47] Electronic searches were conducted in the databases PubMed, APA PsycInfo and SportDiscus, from database inception up until Feb 1, 2021. The primary MeSH headings used were 'stress disorders, post traumatic' or 'posttraumatic stress disorder' AND 'exercise' or 'exercise therapy' or 'physical fitness' or 'sports' ("*Documentation of search strategies"* available at OSF, https://osf.io/pr9vc).

After deleting duplicate studies, the remaining articles were then independently evaluated by both authors for eligibility based on the inclusion criteria: the study was published in English, was a randomised controlled trial, participants (adult men and women) had a PTSD diagnosis according to the definition by Diagnostic and Statistical Manual of mental disorders (DSM), International Classification of Diseases (ICD), or clinically significant PTSD symptoms as indicated by baseline scores above threshold on a validated scale, and participants were randomly allocated to either a non-exercising control group or an exercise group participating in different types of aerobic or anaerobic activity. There was no restriction on time passed since trauma, or the cause of PTSD. For all studies that met the inclusion criteria, additional searches of their bibliographies were then performed. The bibliographies of five recently published and relevant reviews[25-29] were also searched.

Data analysis

The following data were extracted from the remaining studies: number of participants (n), age, population, % women, diagnostic criteria (instrument), treatment (type of exercise), control group conditions, total training volume (hrs), PTSD outcome measures (PTSD symptoms/diagnosis/remission), and secondary outcome measures (dissociative symptoms, quality of life, sleeping difficulties, and symptoms of a coexisting condition (including anxiety, depression, and substance use disorders [alcohol and drugs combined]). Any necessary modifications to the variables were made in line with recommendations in the

Cochrane Handbook.[48] If more than one participant group received an intervention, pooling of groups were conducted.[49] If results were presented for several periods of follow-up, the longest follow-up from each study was selected.[46, 49] If a study presented more than one measurement of the main outcome, the treatment with the highest number of participants was chosen.

Risk of bias in the included studies was assessed, specifically: selection bias, performance bias, attrition bias, detection bias, and reporting bias. The grading of bias (low, moderate or high) was performed in line with the Grading of Recommendation Assessment, Development and Evaluation (GRADE) guidelines,[50, 51] using grading forms from the Swedish agency for Health Technology Assessment and Assessment of Social Services (SBU).[52] We also investigated how many of the studies included in the current meta-analysis were registered in a trial registry. Publication bias was evaluated using funnel plots.

To test the robustness of the review conclusions, a subgroup analysis was performed for the primary outcomes. The pre-planned subgroup analysis included study quality, high or low training dose, military trauma versus non-military traumas, type of intervention (yoga versus other exercise), active or passive control condition, and group training versus individual exercise. The examination of total training volume was conducted by dividing the studies from the median training volume during the whole intervention, resulting in low dose (≤ 20 hours) and high dose (> 20 hours). Furthermore, we studied the secondary outcomes available in the included studies. This sub-group analysis included dissociative symptoms, quality of life, sleeping disturbances and symptoms of a coexisting condition such as depression, anxiety and substance abuse.

Statistics

Jamovi (Version 1.6) [Computer Software][53] was used to conduct all data analysis. Effect sizes (ES) were computed with random effects models. Extracted pre- and post-training data for each group were reported as mean, SD, and N. All other extracted variables were presented as standardised mean differences (SMD) between treatment groups, and corresponding 95% CI. Meta-analysis was performed with a mixed-effects model and restricted maximum likelihood (ReML) as model estimator. An ES ≥ 0.2 was considered a small effect, ≥ 0.5 a moderate effect, and ≥ 0.8 a large effect.[54] The amount of heterogeneity (*i.e.*, tau^2) was estimated using the restricted maximum-likelihood estimator. The Q and I^2 statistic were used to assess and to quantify the heterogeneity, respectively. A score of >75% was considered to indicate high heterogeneity, I^2 of 50% was considered to indicate moderate heterogeneity, and an I^2 of ≤25% was considered to represent low heterogeneity.[55] Level of significance levels was set to $p < 0.05$.

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The protocol was pre-registered at OSF (https://osf.io/z3jta) registration DOI 10.17605/OSF.IO/Z3JTA.

Results

Results from the literature search and evaluation of studies are summarised in the PRISMA flow chart (Fig. 1). The electronic searches yielded 133 records. Searches using additional sources yielded one relevant record.[56] Twenty-six duplicates were removed, and after initial screening, 29 studies were full-text reviewed for eligibility (28 from database searches and 1 from bibliography searches). A further 18 articles were then excluded, resulting in 11 included studies: 10 articles reporting primary outcomes,[44, 46, 49, 56-62] and one article reporting secondary outcomes.[63]

Characteristics

The total number of participants in the included studies were 605 men and women aged 18-78 years. Of these, 327 participants were randomly assigned to exercise, and 278 to control groups. Study populations were mixed and included both military and non-military trauma. None of the studies included participants with acute trauma, or trauma occurring within 2 months of data collection.

Exercise interventions in the included studies consisted of yoga (all types of yoga), or aerobic (*e.g.*, walking, swimming, cycling, running) and anaerobic (*e.g.*, resistance training, sprinting and high intensity intervals) exercise, either alone or in combination. Control conditions included waitlist control, control group with treatment as usual (TAU), and/or any other intervention (non-exercise or inactive attention-placebo control). Control groups with TAU continued to receive the standard of care provided in medical centres and rehabilitation facilities, particularly participation in psychotherapy and/or psychoactive medication.

Five of the studies used yoga or yoga-like interventions, and five used mixed exercise intensity interventions (two studies used primarily resistance training, and three studies used mixed activities and/or individual exercise prescriptions). Intervention duration varied between three and 20 weeks, and the median total volume of activity in the interventions was 20 hours. Huberty et al. used a three-armed study design with two intervention groups (low dose yoga 60 min/week and moderate dose yoga 150 min/week), and due to pooling of the intervention group, this study was not included in the subgroup analysis of total training volume. Mitchell et al. studied a mixed population of both civilians and military veterans and the study was thereby excluded from the subgroup analysis due to the cause of PTSD. Study characteristics are presented in Table 1.

The studies were of moderate or low-quality regarding bias according to the five domains included in the SBU instrument.[52] All identified biases categorised by the five different domains can be found in Supplementary material, Table 1S. Publication bias was studied using the Begg and Mazumdar rank correlation and Egger's Regression. Results showed no signs of funnel plot asymmetry ($p > 0.99$ and 0.34, respectively) (see supplementary Fig. 1S). Seven of the included studies were registered in a trial registry: ClinicalTrials.gov [44, 49, 58-61] and the Australian and New Zealand Clinical Trials Registry.[57]

Primary effect of exercise interventions

There was a positive effect of exercise on PTSD symptom severity compared to non-active treatment (ES = 0.46, 95% CI 0.18 to 0.74; $p < 0.01$), as shown in Fig. 2. The observed standardised mean differences ranged from -0.02 to 1.53, with most estimates being positive (80%). One low quality study was potentially overinfluential (1.53, 95% CI 0.89 to 2.17).[56] When excluded, the effect decreased to 0.29 (95% CI 0.10 to 0.49, $p < 0.01$).

There were no significant interactions from any of the performed subgroup analyses (Table 2 and Fig. 2S-7S), but there was a borderline significant interaction favouring more voluminous (>20 hours) exercise interventions compared to less voluminous (ES = 0.77 [95% CI 0.20 to 1.33] and ES = 0.26 [-0.03 to 0.55], respectively, $p = 0.07$). In contrast to our initial hypotheses, there were no significant differences between either high or low intensity activities (yoga versus other exercise), or group and individual exercise.

According to the Q-test, the true outcomes appear to be markedly heterogeneous ($Q(9) = 23.6$, $p < 0.05$, $tau^2 = 0.12$, $I^2 = 59.90\%$).

Secondary outcomes

Significant positive effects of exercise intervention were found on depressive symptoms (ES = 0.20, 95% CI 0.01 to 0.38, $p < 0.05$), and an even larger effect was found for sleep (ES = 0.51, 95% CI 0.29 to 0.73, $p < 0.01$). Beneficial intervention effects were also found through reduced substance abuse (ES = 0.52, 95% CI 0.06 to 0.98, $p < 0.05$), and increased quality of life (ES = 0.51, 95% CI 0.34 to 0.69, $p < 0.01$). Only one study presented measures of dissociative symptoms (ES = 0.35, 95% CI -0.14 to 0.84, $p = 0.16$).[44] Regarding anxiety, no significant effect from exercise intervention was found (ES = 0.18, 95% CI -0.15 to 0.51, $p = 0.41$). Forest plots for all secondary outcomes are presented in Fig. 8S-13S.

Discussion

The present review showed there was an overall beneficial effect of exercise on PTSD symptoms, with no significant moderating effects from the selected variables. The results also indicated positive effects of exercise on secondary symptoms, including depressive symptoms, sleep disturbances and substance use disorder. Effect sizes were small to moderate, with one study being potentially overly influential (Jindani et al., 2015). Results from the included studies showed substantial heterogeneity.

In line with our findings, Rosenbaum et al. reported that exercise is efficacious compared to usual care or waitlist in reducing PTSD symptoms in adults, with a small to moderate effect size (Hedges g -0.35). Their meta-analysis comprised of data from four RCTs that were published between 2014 and 2015, and exercise intensity in the interventions varied from aerobic training to yoga.[27] Other previous reviews of PTSD and exercise have examined specific activities (*e.g.*, yoga) or included a narrow range of exercise intensities,[26, 28, 29, 42] such as Hegberg et al. focusing on aerobic training alone. Interestingly, Kysar-Moon et al. found no pronounced effect from yoga interventions as treatment for PTSD, but only two of their three included studies reported PTSD symptoms as a main outcome.[29] Even though the inclusion requirements of the present review differed from previous systematic reviews by Oppizzi et al. and Hegberg et al. who included both experimental and observational studies in adolescent and adult participants of both sexes, the general findings of these observational studies supported the positive effects of physical activity and exercise for reduction of PTSD symptom severity.[25, 26]

Regarding secondary symptoms in PTSD patients, data from Rosenbaum et al. showed that exercise interventions were significantly more effective at reducing depressive symptoms than control conditions (Hedges g -0.37). Comorbidities were also addressed in a review by Oppizzi, concluding that exercise and physical activity have a beneficial effect on anxiety, depression, poor sleep quality, and cardiovascular risk.[25] These previous findings are in line with the results in the present review. For depression and anxiety, lifestyle in general and physical activity in particular has been shown to display clinically meaningful effects on disease severity and even remission rates.[30-34, 36] A common finding across studies is that different types of exercise (high or low intensity) seem to present similar effects.[30, 32, 34] The present review found no differences between type (intensity) of exercise and beneficial effects on PTSD symptom severity.

Interestingly, when compared, aerobic exercise and traditional Chinese exercises have disparate effects on depression and stress in a mixed, young population.[64] However, no such comparable data is available for individuals meeting the criteria for PTSD. The large proportion of the heterogenity between studies can be attributed to differences in study design, inclusion criteria, control conditions and outcome variables. To be able to deliver more precise recommendations, future studies should be more comparable, and there is a need for consensus and agreement between research groups.

The potential mechanisms for the positive effects of exercise in patients with mental illnesses are not fully understood, but the anxiolytic and anti-depressant effects may come from alterations of the kynurenine metabolism,[37] effects on neurogenesis via the PGC1alpha-FNDC5-BDNF,[38] and normalization of the HPA axis function.[39] Up until today, no studies have examined the effect of exercise in brain structure or physiology in PTSD patients. However, the observed overlap amongst the neuronal correlates of PTSD and the brain regions impacted by aerobic exercise[40] indicate that the general exercise-induced brain changes may also positively impact PTSD and its associated comorbidities. Other possible contributors to the positive effects on the observed neurological and health changes associated with PTSD may include regular habits, social interactions, or improved sleep. These factors may partly explain why there was no difference between type of exercise in the present review.

In contrast to our initial hypotheses, we found no significant differences between group and individual exercise. In the included studies, all interventions except one (online yoga) included regular human interaction with a personal trainer, yoga teacher or physiotherapist. Individual coaching was often provided, but the vast majority of guided exercise sessions and yoga classes were conducted in a social setting. Social interaction and regular habits may have contributed to the positive effects. It is worth noting that the participants who dropped out of the online study reported they enjoyed participating in the web-based exercise classes, and that had the study included an online social support group, they would have been more likely to continue.[49] Social support is a well-known behaviour strategy to increasing compliance and attendance to behavioural interventions.[65]

Control conditions in the included studies varied between waiting list, assessment controls and TAU, which may have contributed to more complex results. These factors may influence the general PTSD symptomology and diminish the true effect of exercise. Exercise compared to other treatments is likely to yield smaller effect sizes than exercise compared to no intervention. It would be useful for further studies to investigate how much the effect of increased social interaction is beneficial to PTSD patients.

Military duty is often physically demanding, and exercise is part of the daily routine. Several of the RCTs that included military veterans reported that the participants experienced high satisfaction with the exercise intervention.[46, 60, 61] Continuing exercise is a feasible treatment in PTSD patients, and most of the included studies reported no adverse events and/or none or few negative experiences in concordance with the exercise.[46, 49, 57, 59, 61, 62] Patients with PTSD are not traditionally targeted for health promotion interventions, but exercise is well tolerated by people with anxiety and stress-related disorders, and the drop out rate in RCTs is comparable to control conditions.[66] Regarding the choice of exercise intensity and activity type, health care professionals can develop interventions rather freely. It has been unclear as to whether intervention length has a moderating effect on reducing PTSD symptom severity, or not.[25] The results from the subgroup in the present review suggests a preferred total volume more than 20 hours of exercise.

The present review has several limitations. Firstly, data extraction included some modelling to avoid the same group of participants being included twice in the same meta-analysis, and to address the problem with measures from more than one time point. For example, the longest follow-up from each study was selected, and it is worth noticing this may have created lowered consistency and thereby induce heterogeneity.[48] Secondly, the high variability between studies, as indicated by the marked heterogenity, may obscure important details yet to be identified. Moreover, the test for detecting heterogenity has low power when there is a low number of eligible studies.[67] The low number of studies also influenced the total number of analysed subjects, which weakens the result. Most importantly, the results lack support from low-bias studies.

The participants included in the studies are often homogenous, and studies with a relatively young and habitually physically active population may find a lower effect of exercise than in an inactive population. Future RCTs should use larger cohorts and more exact measurements of exercise intensity and training volume. Furthermore, the study setting for the control group should be determined based on the theoretical background and specified aims of the study (*e.g.*, effect of different exercise intensity, influence of social support, etc).

Conclusion

Results from the meta-analysis indicated reduced PTSD symptom severity following exercise intervention. The effect was most noticeable in a larger volume of more than 20 hours of exercise, which indicates that up to a point, more exercise may provide more benefits. Significant positive effects of exercise were also found for depressive symptoms, sleep, reduced substance abuse and increased quality of life. However, there were no differences found between type of exercise, or group and individual exercise.

Further studies are required to determine the optimal type, dose, and duration of activity needed to reduce PTSD symptom severity. Current research lacks a common focus and primary studies often suffer from methodological limitations. More research is needed to understand the mediators and mechanisms behind the potential benefits of exercise in PTSD patients. With these limitations and identified need to clarify what type and amount of exercise is most beneficial to persons with PTSD, we suggest that there is enough evidence to justify the inclusion of exercise as a part of PTSD treatment.

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Conflict of interest statement

There are no conflicts of interest for any author.

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Figure legends

FIGURE 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the literature search.

FIGURE 2. Forest plot of the main effect of physical activity on posttraumatic stress disorder (PTSD) symptoms ($p < 0.01$). The square and its size represent the estimated intervention effect and the relative weight of each study, respectively. The horizontal line represents the 95% CI. The rhombus represents the pooled effect.

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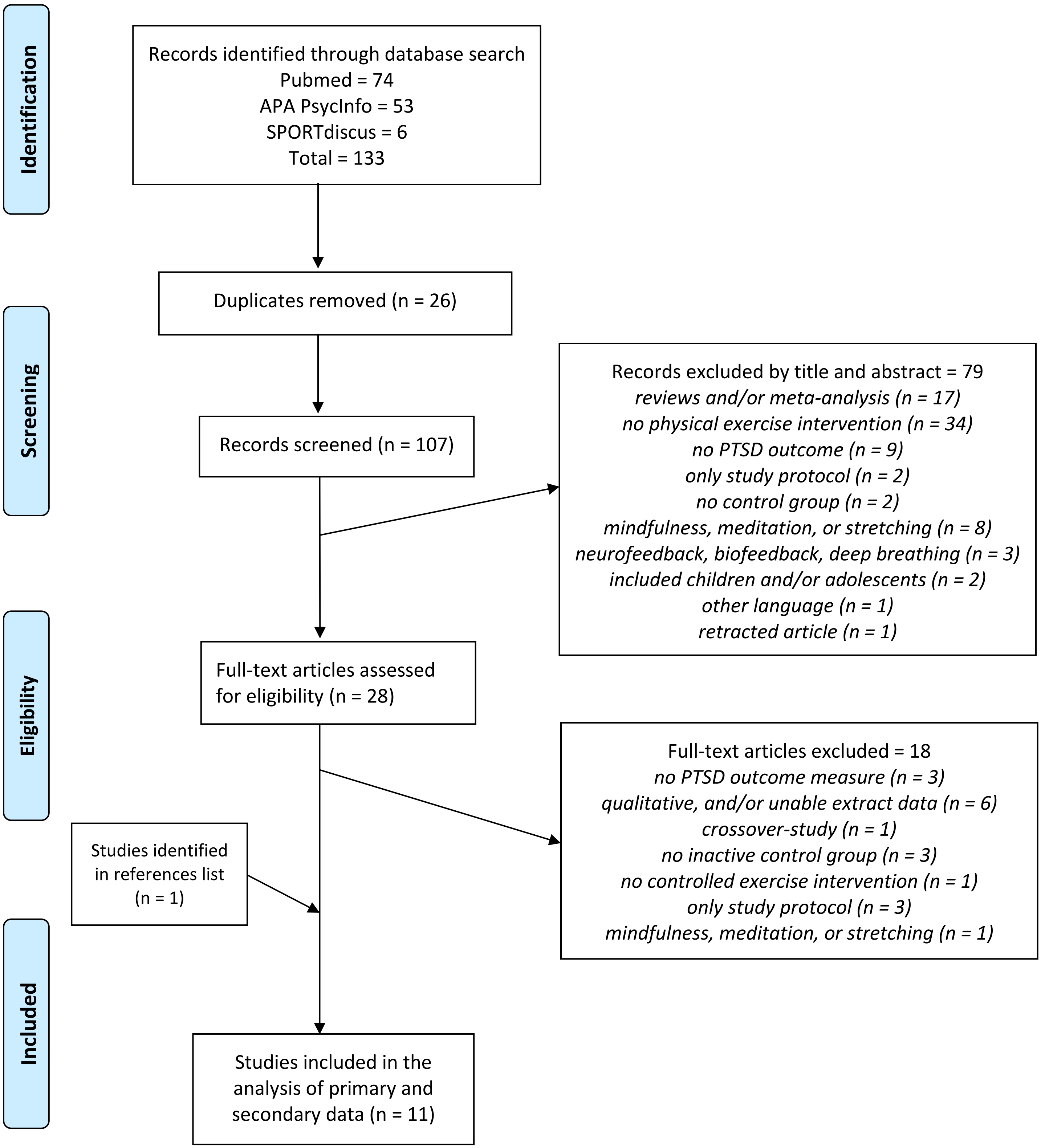

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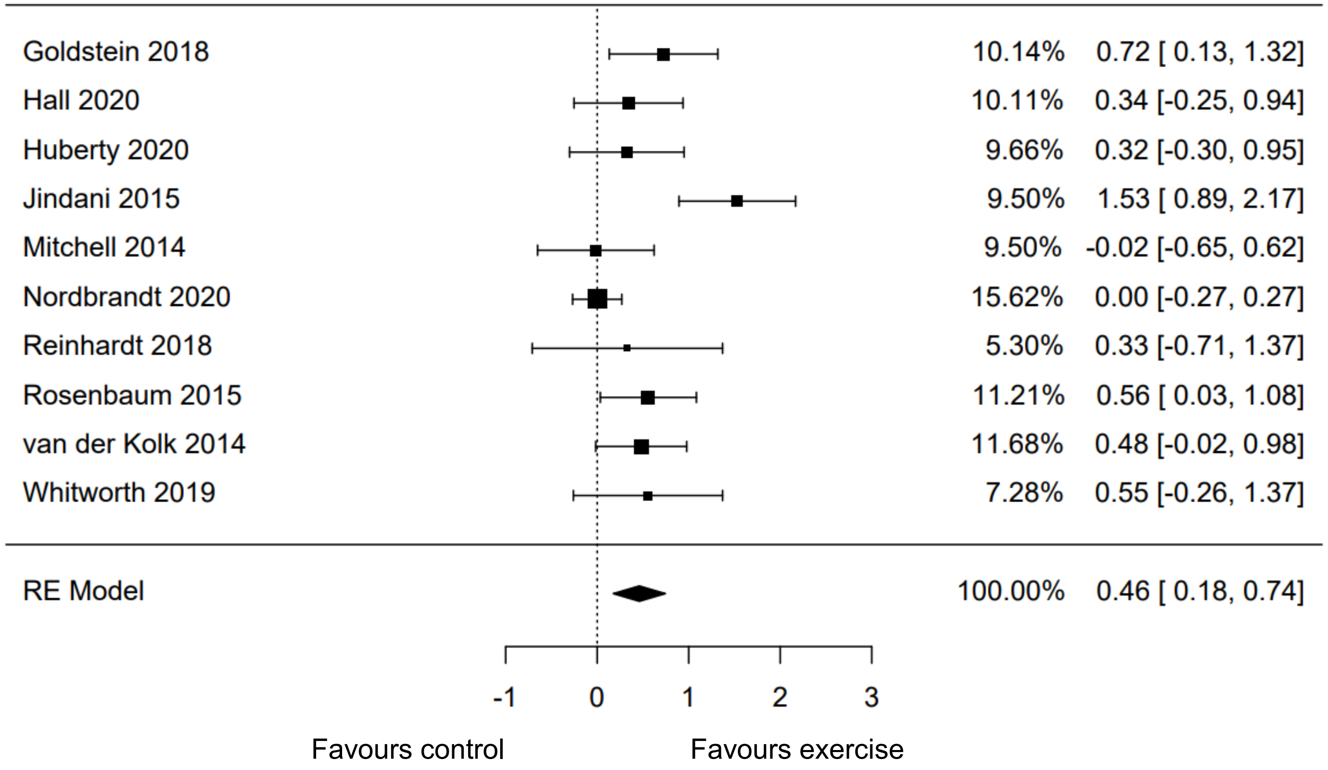

TABLE 1. Study characteristics.

Study	*n*	Included in analysis	Population	Age, mean (SD) yrs	% women	Diagnostic criteria (instrument)	Treatment	Total training volume (hrs)	Control	PTSD outcome measure
Goldstein et al., 2018	47	47	Military veterans, men and women, age 18–69 years, USA.	46.8 (14.9)	19	DSM-IV, full or subthreshold PTSD. (Structured Clinical Interview for DSM-IV-TR Axis I Disorders)	Exercise, group, supervised. Mixed aerobic and resistance training. 12 weeks, 3x60mins/week	36	Waitlist (monitor only)	CAPS (past month)
Hall et al., 2020	54	48	Military veterans, men and women aged ≥ 60 years, registered for care at the Durham Veterans Affairs Medical Center, USA.	67.4 (3.6)	9.3	DMS-V, meeting diagnostic criteria for PTSD. (CAPS, no score)	Exercise, one-on-one, supervised. Mixed aerobic and anaerobic, individualized exercise prescription. 12 weeks, 3 days/week, total: 150mins/week	30	Waitlist/TAU	PCL-5
Huberty et al., 2020	90	48	Stillbirth mothers, recruited via non-profit stillbirth-related organizations (e.g., Stories of Babies Born Still, Mothers in Sympathy and Support Foundation), social media, and hospital/clinics, USA.	NR	100	DSM-IV, meeting diagnostic criteria for PTSD. (IES-R)	Yoga, individual. Hatha based yoga videos from an online streaming platform. 12 weeks, Low dose: 60mins/week Moderate dose: 150mins/week	Low: 12 Moderate: 30	Attention-placebo (stretch and tone-videos from an online streaming platform)	IES-R
Jindani et al., 2015	80	50	Community, men and women aged ≥18 years, Canada.	Median: 41.0 (range 18-64)	88	DSM-IV. (PCL-17 >57)	Yoga, group. Kundalini yoga. 8 weeks, 90mins/week, + home sessions	26	Waitlist/TAU^	PCL-17
Mitchell et al., 2014	38	38	Women (9 veterans, 29 civilians), age 18–65 years, recruited from VA medical center and Craigslist, USA.	44.4 (12.4)	100	DSM-IV, full or subthreshold PTSD diagnosis during in-person interview.	Yoga, group. Trauma-sensitive yoga with elements of Kripalu yoga *(Hatha yoga)*. 12 weeks once/week, or 6 weeks with 2×week.	15	Assessment Only Control^^	PCL-C
Nordbrandt et al., 2020	338/224*	213	Men and women aged ≥18 years, patients at the Competence Centre for Transcultural Psychiatry, an outpatient clinic treating trauma affected refugees, Denmark.	44.6 (10.3)	53	ICD-10, clinically diagnosed by medical doctor.	Exercise, one-on-one, supervised. Aerobic and anaerobic, light physical exercises. 20 weeks, 60mins/week	20	TAU	HTQ
Reinhardt et al., 2018	51	15**	Military, men and women ≥18 years, active-duty personnel and veterans, USA.	45.4 (13.3)	12	DSM-IV, PTSD diagnosis. (SCID-CT)	Yoga, group. Kripalu yoga. 10 weeks, 2×90mins/week, + home sessions	47.5	Control/Waitlist (no-treatment assessment-only control group, self-selected waitlist)	CAPS (past month)
Rosenbaum et al., 2015	81	58	Men and women aged ≥18 years, from the in-patient unit at St John of God Health Care's Richmond Hospital, Australia.	47.8 (12.1)	16	DSM-IV, psychiatrist-confirmed primary PTSD. (PCL-C > 45)	Exercise, individual/small group, supervised. Mixed/Resistance training 12 weeks, 30min/week, + 2×30mins/week home sessions	18	TAU (usual in-patient care)	PCL-C
van der Kolk et al., 2014	64	64	Community, women, age 18–58 years, recruited from commercial ads, research website, and mental health specialists, USA.	42.9 (12.1)	100	DSM-IV, meeting diagnostic criteria for PTSD. (CAPS > 45)	Yoga, group. Trauma informed yoga classes, with influence from Hatha yoga. 10 weeks, 60mins/week	10	Attention-placebo (women's health education classes) + TAU	CAPS (past month)
Whitworth et al., 2019	30	24	Community, men and women, age 18–45 years, non-treatment-seeking adults who screened positive for PTSD, USA.	29.1 (7.4)	73.3	DSM-V, positive screen for PTSD and anxiety. (PDS5)	Exercise, individual, supervised. Resistance training, weightlifting. 3 weeks, 3x30mins/week	4.5	Attention-placebo (health education classes)	PDS5

Abbreviations: DSM = Diagnostic and Statistical Manual of Mental Disorders; CAPS = Clinician Administered PTSD Scale; IES-R = Impact of Event Scale; PCL-C = Posttraumatic Stress Disorder Checklist–Civilian Version; PCL-M = Posttraumatic Stress Disorder Checklist–Military Version; PDS = Posttraumatic Diagnostic Scale; PSS-I = PTSD Symptom Scale-Interview; PTSD = posttraumatic stress disorder; SCID-CT = Structured clinical interview for DSM IV-TR axis I disorders, clinical trials version.

**The total number of subjects (n = 338) represent all three experimental groups; the groups of interest in the present review were exercise and TAU (n = 228).*

*** Of all included subjects (n=51), the crossover-like study design with self-selected control/yoga-waitlist group, and missing datapoints, left only 15 participants eligible for analysis in the present review; 15 subjects with CAPS measurements and 10 or less subjects with values from PCL-M and IES-R scales.*

^Outcome measures for the waitlist group were completed online.

^^Assessment control, 12 weeks of once weekly meetings in groups to complete questionnaires.

TABLE 2. Sensitivity analyses.

	Summary	95% CI	*p* for interaction
Total training dose			
High	0.77	(0.20 to 1.33)	
Low	0.26	(-0.03 to 0.55)	0.07
Activity type			
Yoga	0.54	(0.01 to 1.08)	
Other exercise	0.36	(0.04 to 0.68)	0.61
Group or Individual			
Group training	0.48	(0.16 to 0.79)	
Individual training	0.32	(-0.30 to 0.95)	0.77
Study quality (bias)			
Moderate bias	0.37	(0.10 to 0.65)	
High bias	0.56	(-0.15 to 1.26)	0.61
Control condition			
Passive	0.56	(0.12 to 1.00)	
Active	0.34	(0.03 to 0.65)	0.49
Genesis of PTSD			
Non-military	0.54	(0.12 to 0.96)	
Military	0.51	(0.12 to 0.90)	0.92