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Expert Opinion Article

Light Treatment for PTSD: A Systematic Review

Mohammad Hossein Ghaedamini Asadabadi[1]*, Amir-Hossein Ghaedamini Asadabadi[2], Fatemeh Aliakbari[3], Mobina Saleh[4]

[1]*Student research committee, Shahrekord University of Medical Sciences, Shahrekord, Iran, Email: st-ghaedamini@skums.ac.ir, ry46asadabadi@gmail.com, Tel: +98-9218452903
[2]Student research committee, Shahrekord University of Medical Sciences, Shahrekord, Iran, Email: amir8day@gmail.com
[3]Department of Medical Surgical Nursing, Faculty of Nursing and Midwifery, Shahrekord University of Medical Sciences, Shahrekord, Iran, Email: Fatemeh.aliakbari@flinders.edu.au, m1k3science@gmail.com
[4]Student research committee, Shahrekord University of Medical Sciences, Shahrekord, Iran, Email: salehmobina139@gmail.com

***Corresponding Author:** Mohammad Hossein Ghaedamini Asadabadi
*Student research committee, Shahrekord University of Medical Sciences, Shahrekord, Iran, Email: st-ghaedamini@skums.ac.ir, ry46asadabadi@gmail.com, Tel: +98-9218452903

Abstract
Background and objectives: Post-traumatic stress disorder (PTSD) is a psychiatric disorder triggered by a terror-striking event, causing flashbacks, intrusive thoughts or images, nightmares, sleep disturbances, depressive symptoms, and anxiety. Light treatment has been identified as a possible alternative or adjuvant treatment for PTSD. The present study aims to systematically review the available evidence evaluating the effects of light treatment intervention on PTSD symptoms. Methods: A systematic search was conducted in PubMed, Scopus, Cochrane Library, Web of Science, PsycINFO and ClinicalTrials.gov registry up to February 2024. Controlled trials involving light treatment for PTSD were sought for the review of clinical effectiveness. Results: From 1,805 published and unpublished studies, five studies (n = 280) were included in this systematic review. Two studies used blue light treatment vs. placebo amber light treatment, one study used white bright light treatment compared to inactivated negative ion generator, a pilot trial delivered bright light treatment compared to a sham treatment, and another pilot trial delivered green bright light treatment compared to dimmed light treatment as an intervention for PTSD. Present data indicates favorable effects of blue light and bright light interventions for improving PTSD symptoms. Conclusions: It is becoming increasingly evident that light treatments are effective in treating PTSD. Nevertheless, more studies with greater statistical power are required to provide a solid foundation for recommending light treatment for management of PTSD.

Keywords: light treatment; post-traumatic stress disorder (PTSD); trauma; systematic review.

Post-traumatic stress disorder (PTSD) is a psychiatric disorder that develops in some people who have experienced or witnessed shocking, frightening or dangerous events including war, sexual abuse/assault, physical abuse/assault, being taken hostage or kidnapped, terrorist attack, car accident, natural disaster, (Mann, et. al., Inoue, et. al., & Auxéméry), etc. People may experience a variety of reactions after being exposed to a traumatic event and the majority recover from initial symptoms gradually. However, those who keep experiencing problems may be diagnosed with PTSD (Javidi, et. al. & Davis, et. al.). The most common PTSD symptoms include feelings of isolation, depression, uncontrollable thoughts about the event, anxiety, anger, and irritability (Can, et. al. &, Fitzgerald, et. al.). In addition, patients with PTSD often suffer from sleep disturbances, insomnia, recurrent nightmares, and other sleep problems (Qi, et.al., Miller, et. al., & Brownlow, et. al.). Exposure to direct sun light or artificial light at controlled wave lengths affect circadian rhythms and can be used to prevent or treat a variety of psychiatric disorders (Agorastas, et. al., van der Rhee, et. al., Seber, et. al., Wang, et. al., Nagashima, et. al., & Pail, et. al.). There is a growing body of literature that demonstrates the efficacy of morning blue light treatment on several mental conditions including mood (Glickman, et. al.) and sleep disorders (Bajaj, et. al. &, Raikes, et. al.). Recent research provides favorable outcomes of daily morning exposure to blue light treatment in decreasing fatigue and daytime sleepiness, significant improvements in executive functioning and causing medium to large increases in gray matter volume and functional connectivity in areas and networks which are linked to regulation of sleep and daytime cognitive function, mental alertness along with attention (Kilgrove, et. al.). Moreover, research on light therapies and alternative treatments for psychiatric disorders has shown promising results for bright light treatment as a potential intervention and treatment method for improving

depression/seasonal affective disorder (Pirek, et. al.), anxiety, and sleep disturbances (Lin, et. al.). Given the potential therapeutic effects of different light treatments on common PTSD co-occurring conditions such as anxiety, depression, and sleep disorders, it is optimal to investigate the efficacy of light interventions as affordable treatments with low side-effects for PTSD patients. Therefore, we aimed to systematically review the existing evidence regarding the use of light treatment interventions for PTSD patients.

Method

Protocol and registration

A systematic review was conducted to identify studies which used light therapy as an intervention for PTSD. Our systematic review was in accordance with the preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines (Page, et. al.). The PRISMA statement was developed to provide guidelines for reporting the outcomes of systematic reviews and meta-analyses. It's primarily focused on the reporting of reviews evaluating the effects of interventions and it consists of a 27-item checklist which outlines the sections/topics to be included in a systematic review. In addition, it includes a flow diagram, which provides a visual overview of the different stages of the systematic review, including the identification, screening, and inclusions (and exclusions) of studies. Prior to conducting the preliminary searches, we registered a study protocol for this systematic review in the PROSPERO International Prospective Register of Systematic Reviews in July 2023, registration number: CRD42023439454 (Asabadi, et. al.).

Selection criteria

We included studies of any therapeutic intervention if they involved light therapy aimed at improving the symptoms of PTSD compared with a control group (treatment as usual or routine care/waiting list), or other interventions and treatments for PTSD. We included studies in this systematic review if they were written in English and consisted of adult participants (aged 18 and over). Published studies were eligible if they were published in peer reviewed journals. Moreover, we included studies if participants were diagnosed with PTSD by using validated measures at pre-treatment, and received light therapy for PTSD. We didn't apply any restrictions on the severity of PTSD symptoms or the type of traumatic event. Two reviewers (MGA and MS) completed title/abstract screening and full-text screenings independently and there was no discrepancy about whether a paper was eligible for the present study.

Search strategy

Search methods for identification of studies

We conducted an advanced search in PubMed, Scopus, Cochrane Library, Web of Science, and PsycINFO up to February 2024. We applied filters to exclude animal studies and articles that are considered as secondary studies. We included specific controlled vocabulary terms (medical subject headings [MeSH]) with specific free-text words, related to PTSD, mental health-, and light therapy-related terms (Additional File 1.). The searches were independently peer reviewed by a researcher (AGA) using the Peer Review of Electronic Search Strategies (PRESS) checklist (McGowan, et. al.). To identify studies that are not published in journals, we also searched the ClinicalTrials.gov registry for ongoing studies, unpublished study protocols, and unpublished study results.

Data extraction

Two reviewers (MGA and AGA) performed data extraction independently by using the same data extraction forms; and disagreements in data extraction were resolved through discussion with a third author (FA). We contacted study authors in case there was missing data and if any clarification was needed. We used a standardized data collection form to extract pre-arranged data including the first author, publication year, country of origin, condition, target population, sample size, measurement of PTSD, interventions, outcome, efficacy, duration, follow-up, and adverse effects.

Risk of bias

We aimed to carefully consider the potential limitations of the included randomized controlled trial (RCT) studies and used the Cochrane Collaboration's tool to assess risk of bias (Higgins, et. al.). We explicitly evaluated risk of selection, performance, detection, extent of loss to follow-up, reporting, and other biases (e.g., imbalance in baseline characteristics).

PTSD-related measures

The Structured Clinical Interview (SCID-5; First, et. al.) is a semi-structured diagnostic interview for making diagnoses according to the diagnostic criteria published in the American Psychiatric Association's *Diagnostic and Statistical Manual for Mental Disorders, 5th edition* (DSM-5; Regier, et. al.). The Clinician Administered PTSD Scale (CAPS-5) was used (Boeschoten, et. al.). The CAPS-5 is based on the *DSM-5* and is the gold standard in PTSD assessment. The CAPS (Blake, et. al.) is based on the *DSM-4* (Bell, et. al.) and is the original CAPS diagnostic criteria for PTSD. The Post-traumatic Stress Disorder Checklist (PCL-5) was used to assess PTSD symptom severity (Ashbaugh, et. al.). The PCL-5 is a self-report instrument for PTSD based on the *DSM-5* diagnosis criteria. The PCL-M (military) was also used to evaluate PTSD symptoms (Wilkins, et. al.). The PCL-M is based on the *DSM-4* and was developed to assess

the presence and severity of PTSD symptoms in military personnel.

Results

Search results

We identified a total of 1,780 studies from multiple databases including PubMed, Scopus, Cochrane Library, Web of science and PsycINFO by the search strategy. Additionally, we discovered 25 ongoing studies, unpublished study protocols, and/or unpublished study results in the ClinicalTrials.gov registry. After removal of 683 studies and excluding those clearly not relevant, we assessed the potential studies for full-text eligibility. In case a full text report was not available due to the study's unfinished/unpublished status, we would assess the study based on the posted results on registers if it was feasible. Out of 24 studies assessed for eligibility, 19 studies were excluded, mostly because they were review articles (n = 12), were conference papers (n = 3), and unfinished studies or studies with no study results posted on registers (n = 4). Based on the selection criteria, 5 studies relating to the use of light treatment for PTSD patients were included in this systematic review (Kilgore, et. al., Vanuk, et. al., Youngstedt, et. al., Kawamura, et. al., & Zalta, et. al.). Figure 1 presents the process of study selection in the PRISMA flow chart.

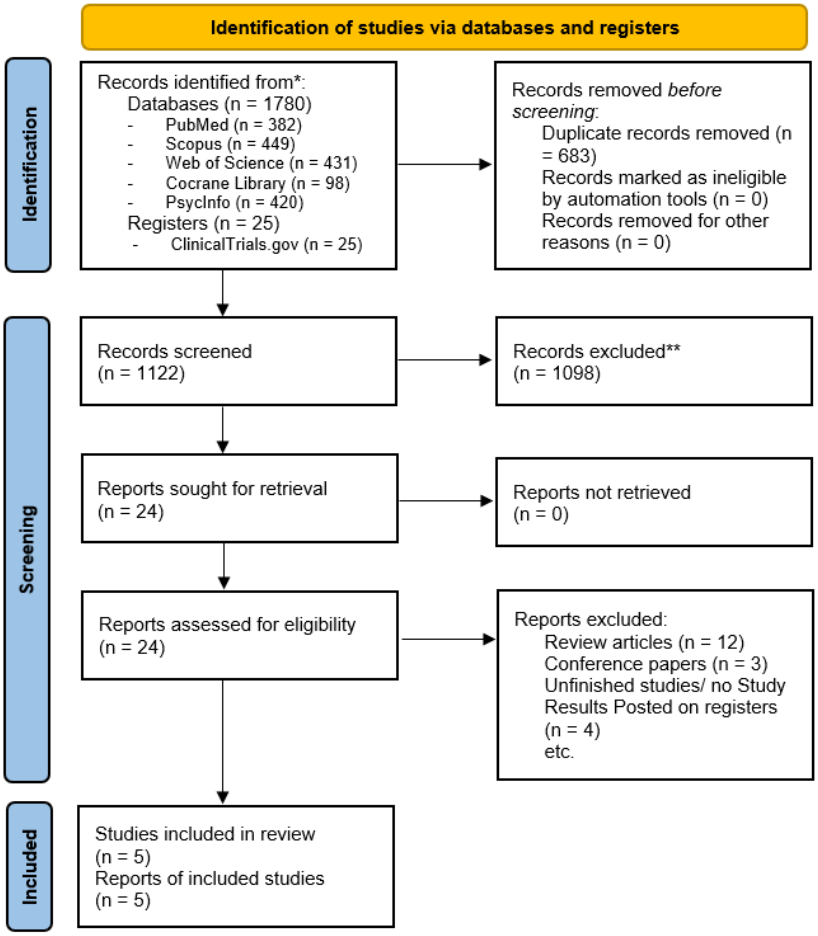

Figure 1 | PRISMA (preferred reporting items for systematic reviews and meta-analysis) flow diagram

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71 For more information, visit: http://www.prisma-statement.org/

Setting and design

All studies were published in English and were conducted in high-income countries. Recruitment methods varied to some extent. Three studies recruited participants based on local advertisements (Kilgore, et. al., Vanuk, et. al., & Zalta, et. al.). In one study, Youngstedt, et al. recruited veteran participants from local primary care outpatient clinics and referrals from mental health staff as well as local advertisements (Youngstedt, et. al.). Kawamura, et al. included patients that were referred by the doctors of a clinical setting (Kawamura, et al.). All studies used RCT designs to evaluate the efficacy of a light treatment intervention compared to a placebo treatment for PTSD. Two

studies delivered blue light treatment versus placebo amber light treatment (Kilgore, et. al. & Vanuk, et. al.,). Youngstedt, et al. delivered bright white light treatment versus inactivated negative ion generator treatment (Youngstedt, et. al.). In a pilot trial, Kawamura, et al. used exposure-based cognitive behavioral therapy (CBT) accompanied by eighter bright light treatment or placebo sham light treatment (Kawamura, et al.). In another pilot trial, Zalta, et al. used green light treatment compared to placebo dimmed light treatment (Zalta, et al.). Therefore, two comparisons between blue light treatment and amber light treatment, one comparison between bright white light treatment and inactivated negative ion generator treatment, one comparison between bright light treatment and sham light treatment following exposure-based CBT, and one comparison between green light treatment and dimmed light treatment are reported. See table 1 and 2.

Participants

A total of 280 individuals participated in the included studies that used light as an intervention to improve PTSD-related symptoms. However, 28 dropped out, and 252 participants completed the studies. Drops-outs mostly occurred due to the lack of time or personal reasons. In two studies, the traumatic events were reported as physical or sexual abuse, accident (e.g., car, work-related), natural disaster, war or combat, and others (Kilgore, et. al. & Zalta, et. al.). In Youngstedt, et al. , the traumatic events were merely related to war or combat (Youngstedt, et al.).

Assessment

All studies but one (Kawamura, et. al.) used validated measures to assess symptoms of PTSD. Killgore, et al. administered the SCID-5 at intake visit, followed by the CAPS-5 at baseline and post-treatment assessment for the participants who were enrolled in the study (Kilgore, et. al.). Vanuk, et al. administered the SCID-5 at intake visit, as well as the CAPS-5 and the PCL-5 at baseline and post-treatment assessment (Vanuk, et. al.). Youngstedt, et al. administered the CAPS and PCL-M at pre-treatment and post-treatment. In Youngstedt, et al.'s study, the PCL-M was later used as a follow-up measure to assess PTSD symptoms in participants (Youngstedt, et. al.). Zalta, et al. used the PCL-5 as a measure for PTSD at pre-treatment and post-treatment (Zalta, et al.). Hence, only two studies used the CAPS-5, the gold standard for diagnosing PTSD.

Interventions

The five included studies aimed at using light therapy to cope with the PTSD-related symptoms. Interventions varied in light wavelengths and number of sessions. Two studies used blue light treatment versus placebo amber light treatment as an intervention for PTSD patients in which every participant was provided with a small light therapy device, fitted with either blue or amber light emitting diodes (LEDs) and was assigned to receive morning light therapy, daily for 30 minutes over 6 weeks (Kilgore, et. al. & Vanuk, et. al.,). Youngstedt, et al. used white bright light treatment compared to inactivated negative ion generator. Each participant in the intervention group received daily exposure of 30 minutes of white light over 4 weeks and each participant in the control group received daily 30 minutes exposure to an inactivated negative ion generator with the same aspects of exposure and over the same time duration (Youngstedt, et al.). In Kawamura, et al.'s pilot trial, participants started a 12-session exposure-based CBT and were randomized at session 3 to receive either bright light or sham light during exposure sessions 3 to 11. Participants were exposed to bright light or sham light for almost 30 minutes and each CBT session lasted 90 minutes (Kawamura, et. al.). Zalta, et al. used a commercial head-mounted device that presented green bright light compared to a similar device that presented dim light. Participants received 1 hour of light treatment each morning over 4 weeks (Zalta et al.).

Killgore, et al. examined the effect of blue light treatment versus amber light treatment on gray matter volume and its link with sleep outcomes in PTSD patients. In this study, objective sleep outcomes from actigraphy measurements provide evidence for the efficacy of blue light treatment on improving time in bed (TIB; *Pearson's* r = 0.27, p *value* = 0.015), total sleep time (TST; r = 0.23, p = 0.042), sleep efficiency (SE; r = 0.26, p = 0.024), and also wake after sleep onset (WASO; r = 0.31, p = 0.007) compared with amber light treatment in PTSD patients. However, blue light did not significantly affect changes in actigraphically measured sleep onset latency (SOL; r = 0.14, p = 0.219). By contrary, subjective sleep outcomes show that light condition did not affect the PSQI (Pittsburg Sleep Quality Index) total score in a significant way (r = 0.01, p = 0.929). In this research, the PSQI which is a self-report questionnaire related to subjective assessment of sleep (Buysse, et. al.) was used as a measure of sleep habits and quality. Nevertheless, using structural magnetic resonance imaging (MRI) on a 3T scanner, authors noticed that participants who were treated with blue light showed increase in the volume of the left amygdala compared to the ones who were treated with amber light (Kilgore, et. al.). In a similar study, Vanuk, et al. examined the effects of blue light treatment versus amber light treatment in regulating sleep and stabilizing circadian rhythms in PTSD patients. Vanuk, et. al. also investigated the effects of light therapy on PTSD symptoms, sleep-related complaints as well as consolidation and retention of extinction memories relative to a fear

conditioning or extinction paradigm. In this study, participants showed improvements in PTSD symptoms and severity between baseline and post-treatment as measured by the PCL-5 *(r* = 0.49, *p* < 0.001) and the CAPS-5 (*r* = 0.60, *p* < 0.001), respectively. Moreover, both groups demonstrated similar improvements in subjective sleep outcomes. Improvements in sleep habits and quality (*r* = 0.34, *p* = 0.001) assessed by the PSQI, impact of daytime sleepiness on function (*r* = 0.23, *p* = 0.031) assessed by the FOSQ (Functional Outcomes of Sleep Questionnaire; Chasens, et. al.), insomnia severity (*r* = 0.44, *p* < 0.001) as measured by the ISI (Insomnia Severity Index; Bastien, et. al.), and disturbing dreams and nightmare severity (*r* = 0.25, *p* = 0.020) examined by the DDNSI (Disturbing Dreams And Nightmares Severity Index; Lee, et. al.) were observed regardless of the study group. Nevertheless, changes in daytime sleepiness as measured by the ESS (Epworth Sleepiness Scale; Johns, et. al.) were not significant (*r* = 0.17, *p* = 0.128). In this study, skin conductance response data demonstrated that daily morning blue light exposure enhanced retention of extinction memory in patients with PTSD and significant group effects were observed for the degree (*r* = 0.27, *p* = *0*.028) and magnitude (*r* = 0.24, *p* = 0.042) of extinction recall at the end of treatment. Moreover, neuroimaging data from using structural MRI on a 3T scanner showed that blue light treatment is associated with a decrease in activation responses within the left insular cortex relative to amber light treatment (Vanuk, et. al.). Youngstedt, et al. investigated the effects of white bright light treatment versus placebo inactivated negative ion generator for combat-related PTSD and attributable morbidity. Participants who were treated with bright light demonstrated greater rate of treatment response (reduction ≥33%) for the CAPS (44.1% vs. 8.6%) and PCL-M (33% vs. 6%). Also, the Clinical Global Impressions of Improvement (CGI-IM) which rated the participants' severity in PTSD at baseline and the end of treatment showed better scores following the bright light treatment compared with the control treatment (*r* = 0.57, *P* = 0.034). The CGI-IM used in this study is a scale that requires the clinician to assess how much the patient's illness has improved or worsened compared to a baseline state following using an intervention (Padhi, et. al.). It is worth mentioning that there was a significant correlation (*r* = 0.47, *P* = 0.04) between shift in actigraphic rest and activity rhythm and the CAPS scores following bright light treatment, while there was no such significant correlation following the control treatment (*r* = 0.09, *P* = 0.65).

In the present study, 63% (*n* = 22) of participants in control group and 59% (*n* = 20) of participants in bright light group were diagnosed with Major Depressive Disorder (MMD) as a comorbid condition. In regards to, the associations of improvement in PTSD and depression, study results reveal that the observed reductions in depressive symptoms on the CAPS were greater (13.8 ± 4.4 to 10.6 ± 5.9, *Hedges g* effect size = 1.10) than reduction of the non-depressive items of the CAPS to some degree (50.1 ± 16.9 to 34.7 ± 21.7, *g* = 0.79). Also, Youngstedt, et al. noticed greater reductions in non-depressive items on the CAPS (53.7 ± 16.1 to 36.7 ± 22.6, *g* = 1.23) for participants with clinical depression than others (45.0 ± 17.2 to 31.8 ± 20.9, *g* = 0.69). However, changes in non-depressive items on the CAPS were not significantly correlated (*r* = 0.33, *P* = 0.058) with changes in the Beck Depression Inventory (BDI) which was used to assess depression in participants (Youngstedt, et. al. & Richter, et. al.). Kawamura, et al. evaluated the efficacy of bright light intervention compared to sham light for treatment of the PTSD and panic disorder patients receiving exposure-based CBT. Participants who received bright light as an intervention had significant improvements in state anxiety (*r* = 0.61, *p* = 0.0426) compared to sham light as examined with the state and trait anxiety (STAI) scale (Julian, et. al.), but there was no significant difference in the STAI trait anxiety score for bright light and sham light (*r* = 0.40, *p* = 0.205). Bright light also greatly augmented the depressive state reduction compared to sham light following exposure-based CBT (*r* = 0.66, *p* = 0.0239) measured using the Montgomery–Åsberg Depression Rating Scale self-rating version (MADRS-S; Ntini, et. al.). However, sleep assessments don't show a significant difference in the PSQI score between bright light and sham light (*r* = 0.58, *p* = 0.052; Kawamura, et. al.). Zalta, et al. evaluated the efficacy of green bright light compared to dim light as a potential treatment for PTSD. In this trial, participants who received bright light as a treatment experienced greater changes in terms of reduction in PTSD (*r* =0.43) and depression symptoms (*r* = 0.35) than the ones who received placebo dimmed light treatment as measured by the PCL-5 and Patient Health Questionnaire-9 (PHQ-9; Kroenke, et. al.), respectively. In this trial, change in the average PCL-5 scores from pre- to post-treatment was larger for the bright light treatment group (pre-*M* (*SD*) = 43.11 (12.77), post-*M* (*SD*) = 28.00 (14.41)) than placebo dimmed light treatment group (pre-*M* (*SD*) = 34.17 (15.33), post-*M* (*SD*) = 31.67 (17.26)), with a higher percentage of participants in the active group achieving a minimal clinically important difference (MCID) in the PCL-5 (66.7 % *vs.* 33.3%) measured PTSD symptoms. Furthermore, sleep outcomes reveal greater improvements in subjective sleep quality from pre- to post-treatment for bright light treatment than placebo dim light treatment but this difference was small (*r* = 0.14). There was a slightly greater improvement in sleep start time for dim light relative to bright light *(r* = 0.14); even though the change in

sleep start times in both groups was extremely small. Sleep outcomes also demonstrate that bright light greatly advanced wake time relative to dim light (*r* = 0.32), decreased WASO from pre- to post-treatment which resulted in a moderate difference in WASO change between the study groups (*r* = 0.23) and decreased TST from -pre to post-treatment (approximately 36 minutes change for bright light vs 0 minutes for dim light) which resulted in reporting a large difference in TST change from baseline to post-treatment (*r* = 0.36) between bright light and dim light (Zalta, et. al.).

Table 1 | Study characteristics of included RCTs

Study	Year	Country	Inclusion criteria	Participant N	Age mean & *SD* (years)	Female %	Study instruments	Planned Follow-up
Killgore, et al.	2022	USA	Individuals between 18-50 years meeting DSM-5 criteria for PTSD; Being right-handed; Being primary English speaker	76	*M* = 31.45 *SD* = 8.83	67.1%	DSM-5 (SCID); DSM-5 (CAPS-5); PSQI; DDNSI; ISI; Objective sleep measures (wrist actigraphy monitoring); Structural MRI	None
Vanuk, et al.	2022	USA	Individuals between 18-50 years meeting DSM-5 criteria for PTSD; Being right-handed; Being primary English speaker	82	*M* = 31.05 *SD* = 8.77	68.3%	DSM-5 (SCID); DSM-5 (CAPS-5); DSM-5 (PCL-5); ESS; PSQI; FOSQ; ISI; DDNSI; Fear-conditioning/fear-extinction protocol; Psychophysiological monitoring with monitoring skin conductance; ECG monitoring; Functional MRI; WASI	None
Youngstedt, et al.	2022	USA	Veterans with PTSD due to combat in Afghanistan and/or Iraq	69	*M* = 36.80 *SD* = -	23.5%	DSM-IV (CAPS); DSM-IV (SCID & PCL-M); CGI; STAI; HDS; BDI; PSQI; Objective sleep measures (wrist actigraphy monitoring)	1-, 4-, and 8-months post-treatment
Kawamura, et al.	2019	Japan	Adult patients with PD associated with agoraphobia or PTSD	10	*M* = 32.00 *SD* = 11.68	70.0%	DSM-5 (CAPS-5); State and trait anxiety scores of the STAI; MADRS-S; PSQI; PDSS-SR; IES-R	3 months post-treatment
Zalta, et al.	2019	USA	Individuals between 18-50 years meeting DSM-5 criteria for PTSD; Being fluent in English	15	*M* = 44.93 *SD* = 11.83	53.3%	DSM-5 (PCL-5); PHQ-9; PSQI; Objective sleep measures (wrist actigraphy monitoring); Treatment adherence; Treatment expectancy, perceived benefit, and blinding	None

RCT = Randomized Controlled Trial | SD = Standard Deviation| M = Mean| PTSD = Post Traumatic Stress Disorder| DSM = Diagnostic and Statistical Manual of Mental Disorders | SCID = Structured Clinical Interview for DSM Disorders | CAPS-5 = Clinician-Administered PTSD Scale for DSM-5 | PSQI = Pittsburgh Sleep Quality Index | DDNSI = Disturbing Dream and Nightmare Severity Index | ISI = Insomnia Severity Index | MRI = Magnetic Resonance Imaging | ESS = Epworth Sleepiness Scale | FOSQ = Functional Outcomes of Sleep Questionnaire | ECG = Electrocardiogram | CGI = Clinical Global Impression | PCL-M = PTSD Checklist-Military | STAI = Spielberger State-Trait Anxiety Inventory | HDS = Hamilton Depression Scale | BDI = Beck Depression Inventory | WASI = Wechsler Abbreviated Scale of Intelligence | | PD = Panic Disorder | STAI = State–Trait Anxiety Inventory | MADRS-S = Self rating version of the Montgomery–Åsberg Depression Rating Scale | PDSS-SR = Self Report version of the Panic Disorder Severity Scale | IES-R = Impact of Event Scale-Revised | PCL = Posttraumatic Stress Disorder Checklist | PHQ = Patient Health Questionnaire

Table 2 | Characteristics of the interventions

Study	Study design	Intervention	Control group	Treatment sessions	Effect size for reduction in PTSD symptoms or severity (*Pearson's r*)	Efficacy	Adverse effects
Killgore, et al.	RCT	Blue light	Amber light	Daily for 30-min over 6-weeks	-	Daily exposure to morning blue light treatment in PTSD patients improved objective sleep duration and increased left amygdala volume compared to amber placebo light treatment	None
Vanuk, et al.	RCT	Blue light	Amber light	Daily for 30-min over 6-weeks	$r = 0.60$	Daily exposure to morning blue light treatment in PTSD patients was associated with improvement in retention of fear extinction memory, PTSD symptoms and sleep-related complaints	None
Youngstedt, et al.	RCT	White bright light	Inactivated negative ion generator	Daily for 30-min over 4-weeks	$r = 0.57$	Bright light treatment effects the primary variables (CAPS and CGI) with clinical relevance (i.e., treatment response) in individual veterans with chronic PTSD	None
Kawamura, et al.	Pilot RCT	Bright light	Sham light	12-session CBT protocol; receiving either blue light or sham light	-	Blue light enhanced the clinical efficacy of exposure-based CBT for PD and PTSD patients	None

				for about 30 min during exposure sessions 3–11			
Zalta, et al.	Pilot RCT	Green bright light	Dim light	Daily for 1 hour over 4-weeks	$r = 0.43$	A higher proportion of individuals who were treated with green light showed a clinically meaningful improvement in PTSD symptoms relative to the ones who received dimmed light	One participant experienced a mild headache on day 7 of the green light treatment

RCT = Randomized Clinical Trial | PTSD = Post Traumatic Stress Disorder| CAPS = Clinician Administered PTSD Scale | CGI = Clinical Global Impression | CBT = Cognitive Behavioral Therapy | PD = Panic Disorder

Risk of bias in included studies

All studies were randomized controlled trials. Therefore, sequence generation for all studies was truly random and at low risk of bias. None of the included studies clarified whether the allocation sequence was concealed until the interventions were assigned. As a result, the risk of allocation sequence concealment bias for is unclear for the included studies. All studies used appropriate levels of blinding and there is no high risk of performance or detection bias. In all studies, the participants included in the analysis were those who were randomized into the trial and there is no included study with an apparent high risk of attrition bias. Most studies used validated measures (e.g., CAPS-5, PCL-5 and PCL-M) to assess PTSD at baseline and post- treatment except for two studies (Youngstedt, et. al. & Zalta, et. al.). No study provided a detailed statistical report on data gathered from the PTSD related measures, and, hence, didn't have a low risk of reporting bias. Overall, the risk of bias is not notable in any included study. The risk of bias is summarized for each study in table 3.

Table 3: Bias of the included studies

	Sequence generation – Selection bias	Allocation sequence concealment – Selection bias	Blinding of participants and personnel – Performance bias	Blinding of outcome assessment – Detection bias	Incomplete outcome data – Attrition bias	Selective outcome reporting – Reporting bias
Killgore et al. (34)	+	+/-	+	+	+	-
Vanuk et al. (35)	+	+/-	+	+	+	-
Youngstedt et al. (36)	+	+/-	+	+	+	+
Kawamura et al. (37)	+	+/-	+	+	+	-
Zalta et al. (38)	+	+/-	+	+	+	+

(+/-): unclear risk of bias; (-): high risk of bias; (+): low risk of bias

Discussion

We intended to evaluate the current available evidence to find out whether light treatment is effective for improving PTSD symptoms. To our knowledge, this is the first systematic review focusing on studies of light therapy interventions for

PTSD patients. The search results indicate that the literature on this topic is scarce. Although there is no notable heterogeneity in study designs. Two studies were small pilot trials but all studies used RCT designs. The available outcomes for PTSD patients who underwent daily exposure to morning blue light treatment were satisfying. Two studies provided evidence to support the hypothesis of positive correlation between sleep quality and PTSD symptom severity and showed that blue light treatment enhances autonomic reactivity and boosts brain function to help fear extinction/safety memory. They showed the efficacy of blue light treatment verses placebo amber light treatment in PTSD patients who had been exposed to various unspecified traumas. These studies used multiple sleep measures and neuroimaging scans to assess sleep and focused on sleep problems in PTSD patients. Findings from both studies support that daily exposure to blue light treatment is a non-invasive procedure and successful therapeutic approach for improving sleep quality and decreasing sleep complaints in patients with PTSD. These studies revealed that daily exposure to blue light treatment over a 6-week period leads to improvements in objective sleep duration, increased left amygdala volume, and greater reactivity in the left insula (Kilgore, et. al & Vanuk, et. al.). Based on the current body of evidence, PTSD patients may experience hypervigilance and increased fear responses due to amygdala hyperactivity (Ousdal, et. al.2000 & Morey, et. al.). Additionally, PTSD is known to cause structural changes in the amygdala as PTSD patients are reported to have reduced volume of the amygdala (Prajjwal, et. al.). Reduction in the amygdala volume might be correlated with PTSD symptom severity several months post-trauma (Ousdal, et. al. 2020), highlighting the potential effectiveness of morning blue light treatment for PTSD. The available evidence also suggests that there is a link between flashbacks in PTSD with insula and sensory area activation (Whalley, et. al. & Zhang, et. al.). Results from the other studies demonstrated the efficacy of bright light as an intervention compared to the placebo treatments (e.g., inactivated negative generator treatment or dimmed light treatment) in patients with PTSD who did not report immensely high habitual light exposure. Based on the outcomes of these studies, bright light treatment, over a period of 4 weeks or along with a 12 session CBT protocol, yields in significant improvements in the CAPS, anxiety and depression outcomes and consequently reduction in PTSD and depression symptoms between treatments (Vanuk, et. al., Youngstedt, et. al., Kawamura, et. al., & Zalta, et. al.). Overall, no indications were found supporting the notion that light treatment aimed to reduce PTSD symptoms would be harmful. Our systematic review highlights the therapeutic potentials of light interventions as non-invasive, affordable, and effective ways with minimum side-effects to improve PTSD symptoms and convince policy makers, scientists, and clinicians to support more high-quality investigations on light therapy interventions, PTSD, and also related conditions including depression, substance use, memory problems, and other physical and mental health disorders. Our results are in agreement with a more comprehensive literature on depression, chronic stress, and sleep disorders, where several light therapy interventions have been found to ameliorate these conditions and vastly improve wellbeing and quality of life in patients (Milad, et.al, Boucsein, et. al., & Campbell, et. al.). This systematic review has multiple limitations, particularly the small number of studies that are eligible to be included in systematic reviews and meta-analyses. The PTSD measurements varied to some extent and some studies lacked to conveniently report on the post-treatment PTSD symptoms assessments based on the valid PTSD measures such as the CAPS-5 or PCL-5. Despite the limitations, we recommend that future studies use the CAPS-5 as the gold standard in PTSD assessment for baseline and post-treatment assessments and consider reporting the PTSD symptoms changes between treatments in detail. Furthermore, future studies should have satisfactory designs: RCT's with sufficient power and low risk of bias, actively monitoring and reporting on any adverse events as well as comorbid psychopathology outcomes.

Conclusion

Our ability to draw solid conclusions is limited due to the small number of studies. More advanced RCTs are needed in order to evaluate the efficacy of light therapy interventions with alternative treatments for PTSD. Yet, given the positive effects of blue light treatment and bright light treatment on sleep problems, depression, anxiety and reducing symptoms severity in PTSD patients, and the fact that no adverse effects have been reported on using light intervention so far, this type of treatment for PTSD is most likely safe and helpful.

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