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The Effect of Physical Activity on PTSD

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ABSTRACT

Although physical activity (PA) is known to reduce anxiety and depression, less is known about the effects of PA on post-traumatic stress disorder (PTSD). The author examined the state of the science regarding the effect of PA on PTSD. Three themes emerged: PA characteristics, added benefits of PA as a PTSD intervention, and theories on the method of action. Physical activity seems to be an effective adjunct therapy to reduce PTSD symptom severity. Findings are inconsistent between observational and controlled studies. More research is needed to identify the most effective type, dose, and duration of exercise.

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SUMMARY STATEMENT

Why is this review needed?

- Post-traumatic stress disorder is a debilitating condition that is growing in prevalence and, if untreated or undertreated, can have significant impact on individuals, families, and ultimately the society at large.
- Traditional treatment includes psychotherapy and pharmacotherapy; however, many who suffer from post-traumatic stress disorder have limited access to these treatment modalities.
- The Institute of Medicine has called for research into cost-effective, complementary treatments to potentiate the traditional method of combined psychotherapy and pharmacotherapy.

What are the key findings?

- Physical activity has been shown to reduce symptoms of post-traumatic stress disorder in persons with subsyndromal symptoms and persons resistant to standard treatment.
- Physical activity has also been shown to improve health conditions that may accompany PTSD (e.g., anxiety, depression, sleep disturbances, and cardiovascular disease).

How should the findings be used to influence policy/practice/research/education?

- Clinicians should include patient-specific exercise prescriptions in their plan of care for treating those with PTSD (e.g., walking program, aerobic activity, or yoga).
- Interventions for persons with PTSD should extend beyond the relationship with the clinician, and include methods that motivate continued exercise.
- Research should focus on the type and amount of activity that is most effective for treating persons with PTSD, including the length of time needed for optimal improvements to be maintained.

Introduction

Post-traumatic stress disorder (PTSD) is a debilitating psychological condition that occurs after exposure to a single or a series of traumatic events that include military combat, terrorism, abuse, rape, childhood neglect, natural disasters, and witnessing injury or death. Traumatic events can also occur indirectly, such as when someone hears details regarding the death or injury of a loved one (American Psychiatric Association [APA], 2017; Newman & Motta, 2007). The DSM-5 defines PTSD as the development of characteristic symptoms (following one or multiple traumatic events) that persist for months, years, or decades (American Psychiatric Association, 2017). There are four defining components of PTSD: negative thoughts, avoidance or numbing, re-experiencing, and hyperarousal.

Background

Negative thoughts include persistent guilt or shame, fear, lack of trust, and/or a general lack of interest in activities or relationships they once enjoyed (APA, 2017). The term *avoidance* is the deliberate effort to avoid experiences, senses, people, or locations that provoke memories of the traumatic event; this also includes emotional desensitization to avoid feelings associated with the traumatic event. This can lead to isolation and makes

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it difficult for the individual to relate to loved ones. The third defining component, *re-experiencing*, occurs when the individual relives the traumatic event through a reminder (e.g., when a veteran hears a firework explode in the sky, it may trigger a memory of a traumatic combat experience). The memories may seem so real that they experience similar feelings of horror that they had when the initial trauma occurred. The final defining component, *hyperarousal*, is when the individual is constantly emotionally heightened. This can lead to problems such as anxiety, insomnia, and difficulty with concentration. These symptoms contribute to substantial social and occupational impairment and poor physical health (Rosenbaum, Sherrington, & Tiedemann, 2015a).

Common treatments for PTSD include psychotherapy (e.g., cognitive behavioral therapy, exposure therapy) and pharmacotherapy. However, many who suffer from PTSD have limited access to these treatments, and scientists within the Institute of Medicine have recognized the need for adjunct, complementary, and cost-effective therapies to increase efficacy of current treatment (Babson et al., 2015; Institute of Medicine [IOM], 2012; Mitchell et al., 2014; Newman & Motta, 2007; Van der Kolk et al., 2014). It is well established that PA has an alleviating effect on anxiety and depression (Babson et al., 2015, Fetzner & Asmundson 2015, Newman & Motta 2007, Rosenbaum et al., 2015a). Though PTSD was once classified by the DSM IV as an anxiety disorder (Newman & Motta 2007), it is now classified as a trauma-and-stressor-related disorder (APA 2013). Anxiety and PTSD share common clinical characteristics and are closely affiliated, yet, they are now recognized as two distinct classifications of psychological disorders; thus, how PA impacts PTSD is not well established. These factors warrant an exploration of current literature on the effect of PA on PTSD symptom severity to inform future research efforts on this topic.

The review

Aim

This paper provides a critical analysis of the research literature related to the effect of PA on PTSD symptoms. It will conclude with a summary of what is known and not known about the effect of PA on PTSD and identify areas for future research.

Design

This is a state of the science review.

Search methods

The first author searched Web of Science, Psych Info, Pubmed, and CINAHL using a university library database system. Article abstracts and titles were searched for the following keywords: *physical exercise, physical activity, exercise, post traumatic stress disorder, and PTSD*. Results were limited to literature published within 10 years and in English language. Manual searches were also conducted using reference lists from publications.

Search outcome

The total number of articles retrieved was 94. The titles and abstracts were screened for relevance, and 13 publications were retained for analysis. Articles that examined the effect of physical activity on other mental disorders and not specifically PTSD were excluded.

Data abstraction

Content from each article was abstracted and entered into a matrix table to allow for appraisal of the relationship between PA and PTSD. Select variables describing the articles included are shown in Table 1 .

Synthesis

Three common themes emerged throughout the analysis: physical activity characteristics, the added benefits of utilizing PA as a PTSD intervention, and current theories on the method of action.

Results

Some authors from these studies explored the effect of PA on PTSD, while others sought to understand what type and length of physical activity intervention is needed to achieve a reduction in PTSD symptoms. This relates to the most effective "dose" or type of activity and the most effective "duration" or length of activity. The study measures, along with primary outcome measures used to evaluate the effectiveness of the intervention in each study are shown in Table 1. Lastly, a summary of current theories on the methods of action were included by some authors.

Physical activity characteristics

The studies included various types and lengths of PA, including aerobic exercise (e.g., bicycling, walking), yoga, and resistance or strength training.

Aerobic exercise. Newman & Motta's (2007) intervention included various aerobic activities of moderate intensity, such as jump rope and jogging. They defined moderate intensity as 60–80% of the target heart rate for 30 minutes at a time. The authors recruited 15 adolescents from a treatment facility who met PTSD criteria; however only 11 were compliant with the entire exercise intervention, and thus 11 were reported in the findings. Changes in pre-post intervention measures within subjects over time had a large effect in reducing PTSD symptoms. Paired sample comparisons using both the Children's PTSD Inventory (CPTSDI) and the UCLA Post-Traumatic Stress Disorder Reaction Index for DSM-IV, Revision 1: Adolescent Version (PTSD-RI) scales suggested a significant reduction in PTSD symptoms in baseline versus post-intervention scores (CPTSDI baseline $M = 19.00$, post $M = 5.90$, $p < .001$; PTSD-RI baseline $M = 31.31$, post $M = 10.27$, $p < .001$). Based on the CPTSDI, all study participants met full criteria for PTSD diagnosis; post intervention, only one (9%) participant did. The score differences for PTSD-RI indicate a reduction in PTSD severity post intervention. Study findings are significant but limited due to a small sample size ($N = 11$).

Babson et al. (2015) also found improvements in PTSD symptoms after an intervention that included aerobic activity. Study participants were male veterans who were in a 60–90 day

Table 1. Selected variables describing the articles in included in the state of the science Review.

First Author, Year	Purpose	Population	Design/Method	Sample Size	Activity Type	Concurrent Treatment	Activity Length	PTSD Measure*	Findings
Babson, 2015	Assess the impact of sleep and exercise on PTSD severity	Male veterans, 24–70 y/o inpatient with PTSD nonresponsive to treatment	Non-experimental, pre/post test design	217	Aerobic (cycling: total days and miles cycled during treatment)	CBT†	Variable, 60–90 day program	PCL-M	No difference in PTSD by PA. However, there was a difference in those with poor baseline sleep quality
Diaz, 2008	Evaluate PA on PTSD symptom severity in adolescents	Females, 14–17 y/o, inpatient‡	Non-experimental, single group, pre/post test design and repeated measures	12	Aerobic-(walking-moderate intensity: 25 min sessions 3x/week)	Residential PTSD treatment	5 weeks	CPSS	Significant reduction in PTSD symptoms post intervention.
Fetzner, 2015	Evaluate if PA has anxiolytic effects on PTSD and if attentional focus has an influence	Civilians, mostly aerobically "untrained"; full and sub-syndromal PTSD	RCT, pre/post test design with 3 equal groups (distraction, interoceptive prompts, and PA alone)	33, 3 groups of 11	Aerobic (cycling, six 20-minute sessions plus any existing pretreatment PA)	No psychotherapy or new psychopharma-therapy in the past 6 months	2 weeks	PCL-C	All groups reported decreased PTSD symptoms over time but no differences were detected between the groups. High loss-to-follow-up at one month required data imputation for almost 50% of the sample.
LeardMann, 2011	Evaluate association of type/amount of PA on PTSD	U.S. service members	Non-experimental, Retrospective analysis of survey data from the Mellennium cohort study.	38,883	Moderate, vigorous, and strength training ranked by 5 categories (very active, active, slightly active, inactive, or cannot be physically active).	Unknown	Variable, self-reported annual survey over a 5 year period.	PCL-C	Odds for developing PTSD or persistent PTSD decreased with activity
LeBouthillie, 2016	To quantify reduction of PTSD as a function of cardiovascular fitness level.	Secondary analysis of Fetzer's 2015 RCT.	Hierarchical linear modeling	32	Aerobic (cycling)	See Fetzer, 2015	2 weeks	PCL-C	Aerobic exercise reduced PTSD symptoms regardless of baseline cardiovascular fitness level.
Mitchell, 2014	Evaluate effect of yoga on PTSD	Females, 18–65 y/o; full and subthreshold PTSD	RCT, pre/post test design groups: 20 Yoga, 18 control	38	Yoga (75 minute session once or twice per week)	Psychotherapy (31.5%), any recent change in psychotropic medication was an exclusion criteria.	6 or 12 weeks	PC-PTSD; PSS-I; PCL	Both groups experienced a clinical and significant decrease in PTSD symptoms (change in total PCL) but there was not a significant difference between groups.
Newman, 2007	Evaluate PA on PTSD, anxiety, and depression in adolescents	Females, 12–18 y/o, Inpatient with PTSD-RI score of at least 25	Longitudinal study, Single group pre/post test repeated measures	11	Mixed moderate aerobic (three 40-minutes group exercises per week)	Individual or group therapy (all), psychotropic medication (54%)	8 weeks	CPTSDI; PTSD-RI	Significant reduction in PTSD symptoms from baseline to post intervention by CPTSDI and PTSD-RI with a large effect.

(*Continued on next page*)

Table 1. Continued

First Author, Year	Purpose	Population	Design/Method	Sample Size	Activity Type	Concurrent Treatment	Activity Length	PTSD Measure*	Findings
Powers, 2015	Evaluate if PA plus exposure therapy increases BDNF levels and enhances improvement in PTSD	Females, 18–65 y/o	Pilot RCT, pre/post test design Small groups: PE with exercise vs PE alone	9	Aerobic (treadmill 30 minutes prior to each PE session)	Prolonged exposure (PE) therapy (90 minutes per week × 12 weeks)	12 weeks	PSS-I	Large between group effect size for increase in BDNF levels and decrease in PTSD symptoms.
Price, 2017	Evaluate effectiveness of extended yoga intervention on chronic PTSD symptoms	Females, 25–55 y/o	Nonrandomized, single-group feasibility study, pre/post test design	9	Weekly, one-hour Trauma sensitive yoga class, home practice 3x/week	Psychotherapy, pharmacotherapy	20 weeks	CAPS DTS DES	Significant reduction in PTSD symptoms
Rosenbaum, 2015a	Evaluate RCTs to date for the effect of PA on PTSD	Adults > 18 Mean ages 34–54 y/o	Meta-analysis of 4 RCT	200	Yoga, aerobic, resistance training	varies	10–12 weeks	PSS-I PCL-C CAPS	Pooled date from all 4 RCTs showed reduction in PTSD symptoms with PA
Rosenbaum, 2015b	Evaluate impact of exercise program on PTSD symptoms	84% male, 16% female, 23–73 y/o, inpatient	RCT, assessor blinded Groups: Usual care ($n = 42$) vs usual care plus PA ($n = 39$)	81	Aerobic, walking plus three 30 minutes resistance sessions each week	Psychotherapy, group therapy, pharmacotherapy	12 weeks	PCL-C	Significant decrease in PTSD symptoms for participants with PA versus usual care alone
Rosenbaum, 2016	To assess the relationship with PTSD severity and other variables on time spent in moderate PA and walking	83% male, 17% female, 47.6 ± 11.9 years, inpatient	Retrospective pooled analysis of prior RCT	76	Aerobic (self-reported PA questionnaire-IPAQ-SF§)	Inpatient therapy as reported above	12 weeks (check)	PCL-C	Significant & negative correlation with walking & PTSD
Van der Kolk, 2014	Yoga compared to education in reducing PTSD	Females, 18–58 y/o with PTSD, nonresponsive to treatment	RCT Groups: Trauma Informed Yoga ($n = 32$) vs Supportive women's health ($n = 32$)	64	Yoga (one hour per week)	Pharmacotherapy	10 weeks	CAPS	Greater PTSD decline in exercise group

* Post-Traumatic Stress Disorder (PTSD) is operationally defined in these studies by using the following instruments: The Clinician administered PTSD Scale for DSM-5 (CAPS-5) is the "Gold standard" for the general population, since it is a structured clinical interview versus a self-report measure. The PTSD Checklist-Military Version (PCL-M) is a revised version of the PTSD checklist for DSM-5 (PCL-5), which is a 20 item self-report measure that is used to monitor, screen, and make a provisional diagnosis of PTSD based on DSM-5 symptoms. Variants of the military version include changes in the rating scale, in instructions, and wording when referring to the index event. The PTSD Checklist-civilian (PCL-C) is a 20 item self-report measure that correlates with the DSM-5 symptoms criteria, and does have differences in the rating scale and is not interchangeable with the PCL-5. The Children's PTSD inventory (CPTSDI) is a clinician administered scale that can be utilized in children aged 6–18 years, and is based on the DSM-IV criteria. The UCLA Post-Traumatic Stress Disorder-Reaction Index (PTSD-RI) is a self-report measure that assesses PTSD symptoms based on DSM-5, and can be used in people aged 6 years and older. The Child PTSD symptom scale (CPSS) is a 26 item self-report instrument that assesses PTSD symptom severity in children aged 8–18 years and is based on DSM-IV, and the PTSD Symptom Scale-Interview (PSS-I) is a 17 item measure and is a semi-structured interview that can be administered by a lay person. It assesses for the presence and severity of PTSD based on DSM-IV. The Davidson Trauma Scale for PTSD (DTS) is a self-reported measure that asseses severity and frequency of PTSD symptoms based on DSM-5 criteria. The Dissociative Experiences Scale (DES) is also self-reported and measures the level of dissociation (Price et al., 2017, Steinberg & Beyerlein, 2013, U.S. Department of Veterans Affairs, 2016).

† Cognitive behavioral therapy is abbreviated CBT.

‡ The term *inpatient* indicates a PTSD treatment facility.

§ The International Physical Activity Questionnaire Short Form (IPAQ-SF) is an instrument that is used to assess physical activity.

inpatient cognitive behavioral therapy rehabilitation program due to treatment resistance. They were invited to volunteer in cycling intervention during their stay. The authors collected data on miles and number of days cycled, and evaluated the dose of exercise by examining PSTD symptoms by three exercise groups [none, moderate (<59.6 miles), and high (>59.6 miles)]. No differences between baseline and discharge PTSD symptoms were detected among participants who did and did not exercise; however, interaction effects among sleep quality and exercise on a PTSD symptom cluster were detected. Those who had poor baseline sleep quality and exercised experienced a significant reduction in hyperarousal symptoms ($\beta = -.24, p = .002$). They concluded that cycling is a beneficial adjunct therapy to treating hyperarousal symptom of PTSD in those with poor sleep quality. Benefits from aerobic cycling were further confirmed by Fetzner and Asmundson (2015), yet, general PTSD symptoms improved and were not isolated to any of its defining components.

Fetzner and Asmundson (2015) conducted a randomized controlled trial (RCT) to examine whether a cycling intervention has anxiolytic effects in PTSD and also explored whether or not a difference in attention and focus during the activity would influence this. Civilians ($N = 33$) who were mostly aerobically untrained with full blown PTSD symptoms or subsyndromal PTSD were randomized into three groups: (1) PA plus interoceptive prompts, (2) PA plus cognitive distraction, and (3) PA alone. Interoceptive prompts meant that the instructor called participants to focus on specific bodily sensations, such as the contraction of a certain muscle group every five minutes during the activity. Cognitive distraction meant participants were directed to view a nature show. They assessed changes in PTSD (total score and subscales) over time in the intervention group using hierarchical models. Each intervention group contained 11 participants; however, almost half of the group participants were lost to follow-up at one month. The authors used imputation methods to account for missing data. The sample size was small; nevertheless, the use of repeated measures increased the power to detect differences. There was a significant reduction ($p < .01$) in PTSD (total and all subscales) symptoms over time within all intervention groups, yet no significant difference in PTSD symptoms between intervention groups. Each group engaged in PA, and participants self-reported clinically significant reduction in PTSD symptom severity in all groups.

Walking has also been utilized as an aerobic PA intervention in PTSD. According to Rosenbaum et al. (2016), it is easily incorporated and translated across settings. Ease of use and acceptance among various populations also enhances participation and sustainability. Diaz and Motta (2008) included a twenty-five-minute moderate-intensity walking intervention, where participants ($N = 12$) self-monitored and reported their heart rates at select moments during the exercise to ensure they were reaching the heart rate goal. The study was a pretest post-test design with no non-active control group. They reported statistically significant improvements in PTSD and trauma symptoms. This was further confirmed by Rosenbaum, Sherrington, and Tidemann (2015a), who had similar findings. They conducted an assessor-blinded RCT that included a walking program combined with thirty minutes of resistance training three times per week. PA was used in addition to usual care versus usual care alone at an inpatient PTSD treatment center. Walking was measured by a pedometer and recorded in a walking diary by participants. The authors reported a significant improvement in PTSD symptoms (primary outcome measure) as assessed by the PTSD checklist-civilian (PCL-C). There was a moderate post-intervention effect between the intervention group as compared to the control (non-active) group (MD $= -5.4$, 95% CI -10.5 to -0.3, $p = .04$). Poor adherence (<20% turned in their walking diaries) to the full intervention prevented the authors from detecting a dose response of PA on PTSD. Results suggested that a walking program that includes resistance training in addition to usual care significantly improved PTSD symptoms as compared to those who only had the usual treatment for PTSD (e.g., psychotherapy, pharmacological intervention, and group therapy).

Based on the above findings, aerobic activity, regardless of the type, has demonstrated a reduction in PTSD symptom severity. Neither study that included cycling interventions demonstrated strong evidence of a reduction in all PTSD symptoms; however, both studies had significant limitations that impacted internal validity of the study (e.g., self-selected groups, unreliable measure of sleep quality, and no non-active control group) and potentially undermined results. Use of a walking intervention also demonstrated an improvement in general PTSD symptoms, though one study sought to achieve aerobic capacity (Diaz & Motta, 2008), while the other did not assess heart rate; instead, these authors included steps taken as a data point (Rosenbaum et al., 2015a). Statistically significant reduction in PTSD symptoms in both cases suggest the need to distinguish whether or not there is a difference between aerobic PA and dose (e.g., steps taken) in reducing symptom severity. Regardless, the studies that include PA with more aerobic tendencies (i.e., jump roping, walking, cycling) suggest that this type of PA can lessen PTSD symptom severity, whether it's a targeted defining component, such as hyperarousal (Fetzner & Asmundson, 2015), or a reduction in general PTSD symptoms over time (Babson et al., 2015; Diaz & Motta, 2008; Newman & Motta 2007; Rosenbaum et al., 2015a).

Yoga. Though yoga is not an aerobic exercise, it has been shown to be beneficial to mental and physical health and hypothesized to reduce PTSD symptom severity (Mitchell et al., 2014; Rosenbaum et al., 2015b). Mitchell et al. (2014) and Van der Kolk et al. (2014) conducted a pilot study that demonstrated that the impact of the group (yoga intervention versus assessment control) was not statistically significant to detect a relationship between the effect of yoga on PTSD symptoms. The authors report a clinically significant improvement in PTSD severity over time in the yoga group (measured weekly by PCL-C during the intervention). A clinically significant reduction in PTSD is defined as a 10 to 20-point change in the PCL-C score (Fetzer & Asmundson, 2015); participants also self-reported that the intervention was a beneficial, positive experience. They did not report any worsening of PTSD symptoms over the course of treatment.

Van der Kolk and colleagues (2014) conducted a study that included a weekly one-hour trauma-informed yoga class for 10 weeks as an intervention. The authors assessed PTSD severity and affect tolerance, which is the ability to tolerate stimuli with appropriate rather than impulsive behavior. During the class, there was a focus on breathing, posture, meditation, and

self-awareness. Participants ($N = 64$) made intentional choices about themselves instead of desensitizing their feelings or acting out of impulse, and the aim of this was to combat this tendency in PTSD. Both groups had a significant decrease in PTSD symptoms, as measured by the Clinician-Administered PTSD scale (CAPS), but the yoga group had a greater decline than the control group (yoga: $b = -9.21$, $t = -2.34$, $p = .02$ and the control: $b = -22.12$, $t = -3.39$, $p = .001$). Post intervention, 16 of 31 (52%) participants no longer met criteria for PTSD versus 6 of 29 (21%) controls, and there was a significant difference between groups ($n = 60$, $x^2 = 6.17$, $p = .013$). Even though there was a lasting reduction throughout the intervention for the yoga group, it is not known if improvements in the yoga group persisted post intervention.

Results of both studies evaluating the impact of yoga on PTSD symptoms are inconsistent. This could be simply due to the fact that one was a pilot study with too small of a sample size to detect a significant difference (Mitchell et al., 2014), while the second had a larger sample size and detected statistical significant changes in symptoms (Van der Kolk et al., 2014). Regardless, both demonstrate some type of improvement in symptoms, even if only clinically significant or patient-reported (Mitchell et al., 2014). This suggests that yoga as a PA may be beneficial to alleviate PTSD symptoms; nevertheless, further research is needed.

Activity Duration. There are mixed findings as to whether or not the length of an intervention has an influence on maintaining psychological benefits. Newman and Motta (2007) conducted a 5-week intervention and found that improvements in PTSD symptom severity were not maintained at one-month post-intervention. Fetzner and Asmundson (2015) conducted a 2-week intervention, and found similar results in their study that explored whether or not aerobic activity had anxiolytic effects in those with PTSD. Participants' PTSD symptoms initially improved, but worsened post-intervention at one week and one month follow ups. Both studies support the claim that a PA intervention should be continued to maintain benefits (LeBouthillier, Fetzner, & Asmundson, 2016, Newman & Motta 2007, Van der Kolk et al., 2014).

More recently, Price et al (2017) utilized a 20-week yoga intervention to treat women ($N = 9$) with chronic, treatment resistant PTSD. Findings demonstrated a significant reduction in PTSD symptom severity, and treatment effects lasted two months after the intervention ended. The former two studies were much shorter in duration compared to the latter. Though the sample size is small, findings suggest that there is an ideal intervention duration with potential lasting benefits of physical activity after the intervention ceases. Further research is needed to distinguish the optimal length of time needed to maintain psychological benefits of physical activity.

Added benefits of PA as a PTSD intervention

Despite the type of PA, a common thread throughout the literature was the peripheral benefits of utilizing PA as part of the PTSD treatment regimen. Some suggest that PA simultaneously improves sleep quality (Babson et al., 2015) and cardiovascular health (Rosenbaum et al., 2015a, 2016). The literature also illuminates the cost-effectiveness of PA and suggests that it is an accessible and effective adjunct treatment (Babson 2015; Rosenbaum et al., 2016).

Poor sleep quality is a substantial concern for those with PTSD since its ramifications are cyclic in nature. Defining components (such as hyperarousal) not only inhibit sleep, but poor sleep quality is thought to compound PTSD symptom severity (Babson et al., 2015; Rosenbaum et al., 2015a). Babson et al. (2015) found an interaction effect between poor sleep quality and PA with one defining component of PTSD. More specifically, those who had poor sleep quality at baseline experienced a significant reduction in hyperarousal after participating in the PA intervention. This study suggests that PA may, in part, reverse the negative cycle of poor sleep and worsening symptoms. PA may directly improve sleep quality, thus reducing hyperarousal symptoms; on the other hand, PA may alleviate the hyperarousal component of PTSD, thereby improving sleep quality. Other studies have determined that an improvement in sleep quality is an important component of PTSD treatment, and it is something that may be simultaneously addressed with a PA intervention (Babson et al., 2015; Rosenbaum et al., 2015a). However, the effect of PA on PTSD related sleep disturbances is largely unexplored and in need of further research.

In addition to improvements in mental health, activity has the added benefit of improving overall physical health (Rosenbaum et al., 2015a, 2016). Not only have studies shown that PA alleviates PTSD symptom severity, but it is postulated to be an intentional way to combat the substandard levels of PA that those with PTSD typically exhibit (LeardMann et al., 2011; LeBouthillier et al., 2016; Newman & Motta 2007; Rosenbaum et al., 2015a, 2016). Rosenbaum et al. (2015a) recognized that cardiovascular risk was a common problem in those with PTSD, and so they included measures to evaluate physical effects of activity as a secondary outcome in their study. These included a PA questionnaire, a 6-minute walk test to determine cardiorespiratory fitness, grip strength, body mass index (BMI), body fat percentage, waist circumference, resting heart rate, and blood pressure. This study was the first to include such measurements—although typical in many physical exercise trials—when evaluating the effect of activity on those with PTSD, and the study results demonstrated an overall improvement in physical health throughout the twelve-week exercise program. Since the lack of PA leads to higher cardiovascular risk, PA can benefit both mental and physical health and should be an important part of a plan of care

Theories on the method of action

In addition to the perceived benefits of this type of intervention, there are specific reasons why scientists hypothesize its efficacy in treating PTSD due to the method by which it works. More precisely, there are distinct avenues by which improvement is said to occur.

Interoceptive exposure. Lower levels of PA are typically seen among persons with PTSD (Rosenbaum et al., 2015a). Consequently, there are lower levels of exposure to "distressing" physical sensations that naturally accompany PA; these physical sensations are known as *interoceptive exposure*. LeBouthillier et al. (2016) theorized that this leads to a higher sensitivity to distressing physical sensations or emotions, as compared

to those who exercise, and thus make these sensations more difficult to tolerate. In their study, those who had lower baseline levels of cardiorespiratory fitness had the greatest benefit to the intervention, since they experienced unfamiliar sensations and became more accustomed to them over time. They concluded that the decrease in hyperarousal and anxiety symptoms were attributed to intentional exposure to "distressing" physical sensations associated with exercise, thus desensitizing them to distressing sensations that accompany PTSD. Fetzner and Asmundson (2015) made a similar claim that exposure to such sensations helps decrease anxiety sensitivity towards otherwise feared somatic sensations. In fact, they hypothesized that participants who were prompted to notice interoceptive sensations (i.e., they asked participants to notice the sensations in legs or to any difficulty breathing) during exercise would experience an even greater improvement than the group that simply exercised without such prompting. This hypothesis was not supported by the findings; in fact, those who were in the group with prompted interoceptive exposure had less of a positive response in regards to PTSD symptoms, as compared to the other two groups. This could be attributed to their attempt to synthetically manipulate the attention to somatic sensation that naturally occurs in PA.

Emotional regulation. Two different studies included yoga as the intervention, with the theory that mindfulness specifically targets the *avoidance* component of PTSD (Mitchell et al., 2014; Van der Kolk et al., 2014). Yoga involves stretching, meditation, and a focus on breathing and bodily sensations with movement. Rather than dissociating themselves emotionally or physically, this activity was hypothesized to help participants learn to tolerate physical sensation as they are coached to become self-aware during the yoga session. Learning to tolerate physical sensations, such as noticing a feeling of fear rather than avoiding it, is said to help participants regulate emotions. Mitchell et al. (2014) hypothesized that emotional regulation through yoga would alleviate re-experiencing symptoms and avoidance. Research findings are mixed regarding this. They found that the impact of group allocation (non-active control group versus yoga intervention group) was not statistically significant when evaluating scores for PTSD. The study may have been too underpowered ($N = 38$) to detect a statistical difference.

Van der Kolk et al. (2014) also included yoga as an intervention, and detected a statistically significant improvement in overall PTSD symptoms in the intervention group ($b = -9.21$, $t = -2.34$, $p = .02$) (Van der Kolk et al., 2014). The authors measured PTSD by the CAPS, and tested it at regular intervals throughout the study to ensure inter-rater reliability. However, the authors did not mention whether or not the CAPS evaluated a specific breakdown in types of PTSD symptoms (negative thoughts, avoidance, re-experiencing, and hyperarousal). This study would have been more informative if such a measure had been used. It would have provided more insight into how yoga impacts PTSD symptoms.

Though both of these studies contained interventions based on prior research, they would have been strengthened if supported by a theoretical framework guiding their interventions. One type of theory that could have supported a yoga intervention that contains a therapeutic mindfulness component is a mind–body theory. Newman and Motta (2007) referred to literature proposing that the mind and body are one entity, which may indicate that physical improvements that are associated with exercise are directly linked to mental improvements.

Physiological effects. Some scientists suggest that the underlying mechanism by which PA is said to affect PTSD symptoms is through physiological processes (Mitchell et al., 2014; Newman & Motta, 2007; Powers et al., 2015). One group of authors argued the case of the neurophysiological impact of yoga and its effect on buffering the body's natural stress response, and thus, short- and long-term cortisol and catecholamine regulation processes (Mitchell et al., 2014).

Powers and colleagues (2015) conducted a study to test brain-derived neurotropic factor (BDNF) as it relates to PTSD treatment. BDNF is necessary for memory, long-term learning, and fear extinction, yet those with anxiety disorders have been shown to have low levels of this protein. The authors reviewed literature indicating that fifteen minutes of aerobic exercise raises BDNF levels; thus, they hypothesized that aerobic activity directly prior to an exposure therapy intervention may enhance outcomes with this current treatment for PTSD. Significance testing was limited by the small sample size ($N = 9$) in their pilot study, yet, effect sizes were calculated and interpreted using *Cohen's d*. They found a very large effect between group pre-test and post-test, with an increase in plasma BDNF levels and a decrease in PTSD symptoms in the exercise intervention plus exposure therapy group, as compared to the control group with only exposure therapy. Although the findings were limited by the small sample size, they provide support—through a measurable biomarker—for the claim that PA is an effective adjunct therapy for PTSD.

Discussion

Overall, there is substantial support in the literature to support the benefit of PA on reducing PTSD symptom severity. Moreover, this has been shown to positively affect conditions that often go alongside PTSD, including anxiety, depression, poor sleep quality, and cardiovascular risk. Intervention types have ranged anywhere from yoga to aerobic exercises, which includes activities such as brisk walking, bicycling, jogging, and jumping rope. Length of time has ranged anywhere from 2–12 weeks. Findings have consistently demonstrated that PA is a useful adjunct or complementary therapy to treatment for subsyndromal to treatment-resistant PTSD (Babson et al., 2015; LeBouthillier et al., 2016; Mitchell et al., 2014; Van der Kolk et al., 2014). Though, it is not determined what type or dose of exercise is necessary for optimal results, the literature suggests that PA should continue beyond the initial intervention to maintain results (LeBouthillier et al., 2016; Newman & Motta 2007; Van der Kolk et al., 2014).

The majority of the studies had small sample sizes (ranging from 9 to 38) with the exception of a few (ranging from 64 to 38,883). In addition, there were several studies that did not have a non-active control group or there were other reasons for study limitations; furthermore, most studies had gender bias (Babson et al., 2015; Diaz & Motta, 2008; LeBouthillier et al., 2016; Mitchell et al., 2014; Newman & Motta, 2007; Powers et al., 2015; Rosenbaum et al., 2015b, 2016; Van der Kolk et al., 2014). Despite this, there were nearly an equal amount of studies that were biased to either females or males with similar results. These

components limit the generalizability of findings, yet, each study contributes valuable input to the early stages of developing the body of research on this subject.

Future research

It is clear that PA has a positive effect on PTSD symptoms; however, the optimal dose (type and duration of PA) is not clear. How does PA affect PTSD—globally, or does it target the individual symptoms? What type of PA is most effective? What is the underlying mechanism of action, and does it vary with different populations? What are other potential confounding or interactive factors in addition to sleep that need to be explored? What is the impact of PA on PTSD symptom reduction in other at-risk populations (e.g., refugee populations, survivors of critical illness)? Refugee populations are at high risk due to traumatic experiences associated with war and violence, and there are language and cultural barriers to PTSD treatment. Exercise is an intervention that can be used across cultures, is more accessible than other treatments, and can be translated to various settings and ethnicities (Diaz & Motta, 2008; Rosenbaum et al., 2016). Post intensive care syndrome (PICS) affects up to one-third of intensive care unit (ICU) patients and includes anxiety, depression, and PTSD (Davidson, 2013). PA can be an ideal intervention that can bridge barriers to standard treatment. It can be applied to those who are unable to fully communicate their thoughts and feelings due to language, cultural, or perhaps even cognitive barriers (such as in PICS). Research should be conducted in these at-risk populations to determine if PA can reduce the PTSD disease burden in these ever-growing populations.

In future research, it is recommended that intervention protocols and exercise doses are standardized to enhance study rigor and strengthen findings (Diaz & Motta, 2008; Fetzner & Asmundson, 2015). Studies should be carefully designed to include a non-active control group and assessment of other potential confounding and treatment factors (e.g., CBT intervention, social support). Loss to follow-up due to location, transportation, and inconvenience for participants has been an issue in existing studies. Future studies need to include interventions in a convenient location (Diaz & Motta, 2008; Rosenbaum et al., 2015a), and include effective strategies to prevent loss to follow-up (Robinson et al., 2015). Interventions should promote motivation to continue the exercise beyond the program, since continuing PA is a necessary part of maintaining effects of treatment (Rosenbaum et al., 2015a).

Objective anthropometric measures should be included as an outcome since this population is at high risk for cardiovascular disease (Rosenbaum et al., 2015a, 2015b). Obtaining these measurements before and after the intervention is invaluable to determine the full picture of how PA benefits those with PTSD. Perhaps this will help justify the use for non-pharmacological interventions as a method to not only improve mental health but physical health as well.

Conclusion

PTSD is a condition that is often associated with anxiety, depression, and poor physical heath that further compound its severity and consequences. If left untreated, it can be debilitating and have a negative impact on an individual, families, and ultimately, society at large. Typical treatment involves combined psychotherapy and pharmacotherapy, however, some are resistant or have limited access to traditional treatment modalities (Babson et al., 2015; Institute of Medicine [IOM], 2012; Mitchell et al., 2014; Newman & Motta, 2007; Van der Kolk et al., 2014). The IOM has called for research into complementary treatments to enhance effectiveness and access to care.

Studies have shown that PA has significant alleviating effects on depression and anxiety symptoms (Babson et al., 2015; Fetzner & Asmundson 2015; Newman & Motta, 2007; Rosenbaum et al., 2015a), but little is known about its effects on PTSD symptom severity. This review of the current state of the science demonstrated that PA also has an alleviating effect on PTSD symptom severity, although some findings are mixed. Most of the studies to date have been small and without standard methodologies. We identified three major themes: PA characteristics, added benefits of PA as a PTSD intervention, and theories on the method of action by which PA impacts symptom severity.

PA characteristics were broad. Studies included varying ranges of intensities (e.g., yoga, walking, cycling, aerobic vigorous strength training) and intervention lengths (2–12 weeks). Aerobic activity showed a reduction in symptom severity, but the dose (e.g., steps taken) of aerobic activity needed to reduce PTSD symptoms is unclear. Studies that utilized a yoga intervention have inconsistent findings, though all demonstrated improvement. Furthermore, it is unclear as to whether or not the intervention length as a moderating effect on reducing PTSD symptom severity. Further studies are needed to determine the optimal type, dose, and duration of activity needed to reduce PTSD symptom severity.

PA in general has added benefits as an intervention for the population, since PTSD is associated with poor sleep habits and cardiovascular health (Babson et al., 2015; Rosenbaum, Sherrington, & Tiedermann 2015; Rosenbaum et al., 2016). There is an association between sleep quality, PA, and PTSD symptom severity; however, the relationship is unclear. Additional research is needed to delineate this relationship. Furthermore, studies demonstrated an improvement in overall physical health, though few included the use of anthropometric measures to evaluate the effect of PA on physical health in this population. We recommend that future studies include these non-invasive measures to evaluate physical effects of the intervention, since this is consistent with PA studies in the general population.

Finally, some scientists postulate methods by which improvements occur. So far, these include interoceptive exposure, emotional regulation, and physiological processes. Interoceptive exposure relates to the distressing sensations that naturally accompany PA, and is suggested to help desensitize those with PTSD to the distressing nature of their symptoms. Emotional regulation is postulated to occur with PA through increasing a sense of self-awareness and control. Physiological processes include neurochemical response to PA (e.g., yoga) that buffers the body's natural stress response. Further research is needed to clarify the process by which PA impacts PTSD symptom severity.

PA has beneficial effects on PTSD symptom severity and overall health; however, recommendations for standardized exercise prescriptions for PTSD in clinical practice are needed.

Before these can be developed for this population, careful attention to study design to allow for comparisons in meta-analysis is needed. Until that time, nurse practitioners can at least recommend PA in accordance with national guidelines (American Heart Association, 2016).

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Declaration of interest

The authors report no conflict of interest.

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