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High intensity resistance training improves sleep quality and anxiety in individuals who screen positive for posttraumatic stress disorder: A randomized controlled feasibility trial

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A B S T R A C T

Purpose: Posttraumatic stress is disorder (PTSD) is a disabling psychological condition that often causes chronic sleep issues. Exercise has beneficial effects on sleep in healthy individuals. However, little is known about the effects exercise on sleep in individuals with PTSD. The purpose of this pilot study was to assess the feasibility of a resistance training intervention on sleep quality, PTSD, anxiety and depression symptoms in individuals who screened positive for PTSD.

Methods: While blocking for gender participants were randomly assigned to either a 3-week resistance training intervention (i.e., 9 total sessions), or a time-matched attention control.

Results: A total of 22 participants were randomized into the study. The mean age was 33.0 years (SD = 13.3), 82% were women, and 77% identified as a racial minority. Over 90% of sessions were attended by both groups. Results demonstrated that the resistance training group reported significantly improved global sleep quality $F(1, 16) = 12.04$, $p < 0.01$, sleep latency $F(1, 16) = 13.45$, $p < 0.01$, and reduced anxiety $F(1, 17) = 5.45$, $p = 0.03$ relative to the control. However, PTSD and depression symptoms did not significantly differ between groups ($p's > 0.05$).

Conclusions: The findings of this study suggest that three weeks of high intensity resistance training can improve aspects of sleep and reduce anxiety in individuals who screen positive for PTSD. The results further support the safety, feasibility, and acceptability of resistance training for this population. These results are preliminary, and should be further verified by larger adequately powered trials.

1. Introduction

Posttraumatic stress disorder (PTSD) is a prevalent psychological disorder that affects between 1.3% and 8.8% of people across the globe (Atwoli, Stein, Koenen, & McLaughlin, 2015). The disabling effects of PTSD include nightmares, flashbacks, avoidance behaviors, increased arousal, and persistent negative mood states. In addition to nightmares, PTSD is also known to have profound negative effects on sleep, such as persistent difficulties falling or staying asleep (AmericanPsychiatric Association, 2013). These chronic sleep issues are often made worse by the presence of other commonly co-occurring psychological conditions, for instance anxiety and/or depression (Kim et al., 2018).

Chronic poor sleep quality is an important clinical issue, as poor sleep quality has been linked to a number of negative health conditions, such as cancer, hypertension, and cardiovascular disease (Sivertsen, Krokstad, Overland, & Mykletun, 2009; Sofi et al., 2014). Despite the strong relationship between PTSD and poor sleep quality, many treatment options for PTSD do not specifically address sleep. For instance, research has consistently shown that poor sleep quality often remains even after undergoing treatment that successfully reduces PTSD symptoms (Pruiksma et al., 2016). Given the persistence of poor sleep quality even after treatment, and the long-term negative health effects attributed to chronic sleep issues, further research exploring interventions for PTSD-related sleep disturbances are clearly warranted.

Exercise may be one such intervention. Exercise offers a potential alternative when traditional forms of treatment (i.e., psychotherapies or medication) are not acceptable. For example, multiple systematic reviews have found significant beneficial effects of exercise (i.e., aerobic, resistance, and combined training) on several indices of sleep (e.g., global sleep quality and sleep latency) in healthy populations and those with mental illness (Kelley & Kelley, 2017; Lederman et al., 2019). There is also emerging observational (Harte, Vujanovic, & Potter, 2013; Whitworth, SantaBarbara et al., 2017b) and experimental (Powers et al., 2015; Rosenbaum, Sherrington, & Tiedemann, 2015) evidence suggesting a beneficial effect of aerobic or combined resistance and aerobic exercise on PTSD symptoms, and co-occurring anxiety and

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depression.

However, it is important to note that the research exploring the effects of exercise on PTSD is still in a nascent state. To date, a majority of the exercise and PTSD research has consisted of cross-sectional observational studies and a small, but growing number of experimental trials. Additionally, the current research has primarily focused on aerobic exercise or combination training (i.e., combined aerobic exercise and resistance training). To our knowledge, there are no published studies examining the standalone effects of resistance training (i.e., weight lifting) on sleep quality, PTSD symptoms or co-occurring anxiety and depression in individuals with PTSD. Expanding this research to include studies of resistance training is important, as resistance training may serve as a potential alternative when aerobic exercise is not desired. For example, resistance training is preferred over running or cycling in some populations, such as depressed individuals, and particularly among men (Ashton, Morgan, Hutchesson, Rollo, & Collins, 2017; Busch et al., 2016). Moreover, prior research has shown that resistance training can improve sleep quality, and other conditions related to PTSD, such as anxiety and depression (Kovacevic, Mavros, Heisz, & Fiatarone Singh, 2018).

Given the above, the purpose of this pilot study was to assess the feasibility of a brief resistance training intervention on sleep quality in individuals who screened positive for PTSD, using a randomized attention-controlled design. Additionally, this study sought to explore the effects of the intervention on PTSD symptoms, anxiety and depression symptoms. We specifically hypothesized that three weeks of resistance training would be feasible, and significantly improve sleep quality, PTSD, anxiety, and depression symptoms relative to the control.

2. Methods

2.1. Procedures

Participants were recruited from the local community using online classified listings (e.g., Craigslist), flyers, and advertisements in a free local newspaper. Interested individuals were instructed to call an independent line to be screened for initial eligibility over the phone. Individuals initially eligible were invited for an in-person eligibility screening. Consenting participants were randomized to one of two parallel arms: a 3-week resistance training group or a 3-week time-matched attention control group, following a two-week run-in period. The randomized condition was sealed in an opaque envelope until the moment of randomization. Randomization was blocked on gender (i.e., block size of 4), using a computerized random number generator (Sealed Envelope Ltd. 2016) to ensure gender-balanced groups, as there are well-known differences in the prevalence of PTSD between men and women (Sareen, 2014), and emerging evidence suggesting that men and women may respond differently to certain treatments for PTSD (Voelkel, Pukay-Martin, Walter, & Chard, 2015) and exercise (Whitworth, SantaBarbara et al., 2017b). Testing/assessments and randomization/interventions were handled by separate research assistants. Participants completing the study received $150 in compensation (i.e., $55 to compensate for 10 round trips using public transportation, and $95 in cash incentives). Regarding sample size, we specifically aimed to randomize at least 10 participants per group to provide estimates of the intervention effect size and variance. The study was approved by the institution's review board. All data were collected on site between January 2016 and December 2016.

2.2. Participants

Participants were urban dwelling men and women, aged 18 years and older, who reported having experienced at least one lifetime traumatic event (e.g., physical or sexual assault, military combat, serious accidents, or life-threatening illnesses), and screened positive for PTSD. Exclusion criteria included medical contraindications to resistance training (e.g., musculoskeletal disorders, heart, lung, or metabolic disorders), pregnancy, and currently engaging in > 60 min of weekly exercise or any resistance training. Additionally, individuals currently in or seeking mental health treatment for PTSD were excluded in order to assess the standalone effects of resistance training on the variables of interest.

2.3. Measures

2.3.1. Demographics and health history

Demographic data collected included age, gender, race/ethnicity, height and weight, education, and income. Additionally, a health history interview was conducted to screen for any contraindications to exercise, and to determine if participants were seeking/currently engaged in treatment for PTSD.

2.3.2. Trauma history and PTSD screening

PTSD screening and symptoms were assessed with the Posttraumatic Diagnostic Scale for DSM-5 (PDS5). The PDS5 is a self-report PTSD screening tool that assesses an individual's trauma history and symptom severity (Foa et al., 2015). Symptoms are measured with 20, 5-point items that indicate the frequency and severity of PTSD symptoms in the past month. The items are ranked from “Not at all” to “6 or more times a week/severe”, and represent each of the updated PTSD symptom clusters in the DSM-5 (i.e., intrusions, avoidance behaviors, negative changes in mood and cognitions, and hyperarousal symptoms) (American Psychiatric Association., 2013).

For scoring, the symptom items are summed for a total PTSD symptom severity score. Additionally, severity scores representing each of the individual symptom clusters can be calculated. Valid total scores range from 0 to 80, with higher scores indicating more frequent/severe PTSD symptoms. The PDS5 has excellent internal consistency ($\alpha = 0.95$) and test-retest reliability ($r = 0.90$) and is strongly correlated with the PTSD Checklist ($r = 0.90$) (Foa et al., 2015). Additionally, receiver operating characteristic analyses have identified a total score of ≥ 28 as the optimal cut off for a positive screening for PTSD (Foa et al., 2015).

2.3.3. Sleep quality

Global sleep quality for the past month was assessed with the full Pittsburgh Sleep Quality Index (PSQI). The PSQI is a self-report 19-item scale that assesses global sleep quality. Additionally, perceived sleep quality, latency, duration, efficiency, disturbances, use of sleep medications, and daytime dysfunction due to drowsiness are individually measured through seven subscales (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Each subscale is scored from 0 to 3, and total scores range from 0 to 21. Higher total scores indicate worse global sleep quality and a cut-point of > 5 indicates poor global sleep quality (sensitivity 89.6% and specificity 86.5%). The PSQI has good internal consistency ($\alpha = 0.83$) and is a valid assessment of global sleep quality (Buysse et al., 1989).

2.3.4. Trait anxiety

Anxiety was assessed using the State-Trait Anxiety Inventory (STAI)-Y2 form (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The STAI-Y2 form is a 20-item sub scale representing trait anxiety. Each item has 4-points, ranking from “Almost never” to “Almost always”. Valid scores range from 20 to 80, with higher scores indicating greater trait anxiety. The STAI has been shown to be a reliable and valid measure of both trait and state anxiety (Spielberger et al., 1983). Additionally, a score of ≥ 45 has been recommended as a cut off for a positive screening for a possible anxiety disorder (Bunevicius et al., 2013).

2.3.5. Depressive symptoms

Depressive symptoms were assessed using the Center for the

Epidemiological Studies of Depression Short Form (CESD) (Radloff, 1977). The CESD is a 10-item self-report scale that assesses the frequency of depressive symptoms in the past week. Each of the 4-point items is ranked from "Rarely or none of the time (< 1 day)" to "Most or all of the time (5–7 days)". Items are summed to represent a total depressive symptom severity score. Valid scores range from 0 to 30, with higher scores representing greater levels of depression severity. The CESD has been found to be a valid and reliable depression assessment in the general population (Radloff, 1977) and in psychiatric populations (Bjorgvinsson, Kertz, Bigda-Peyton, McCoy, & Aderka, 2013), and a score of ≥10 can be used for a positive screening for depression (Andresen, Malmgren, Carter, & Patrick, 1994).

2.3.6. Perceived exertion

The Category Ratio Perceived Exertion Scale (Noble, Borg, Jacobs, Ceci, & Kaiser, 1983) was used to assess the participants' rating of perceived exertion (RPE) during each resistance training session. The Category Ratio Perceived Exertion Scale consists of a single item where participants were asked to rate how hard the exercise session was. The item is ranked from 0 through 10, with 0 representing "Rest" and 10 being "Maximal" effort.

2.3.7. Muscular strength assessment

Muscular strength was tested following the guidelines established by the National Strength and Conditioning Association for determining a multiple repetition maximum (RM) (Haff, Triplett, & National Strength & Conditioning Association (U.S.), 2015). Specifically, using a multiple RM approach in lieu of the traditional 1-RM is recommended when working with inexperienced individuals. Additionally, 1-RM testing is contraindicated for single joint exercises, such as the biceps curl (Haff et al., 2015).

Muscular strength was assessed for the squat, bench press, pulldown, overhead press, and biceps curl. Prior to testing, participants warmed up on a stationary bicycle for 3–5 min, followed by progressively heavier warm-up sets for each exercise. During testing, if a successful 8-RM attempt was made, then the load was increased by 5%–10% for upper body exercises (i.e., bench press, pulldown, overhead press, and biceps curl), and 10%–20% for the lower body (i.e., squat). Participants rested for 2–4 min between each set and exercise and were given three attempts at reaching their 8-RM. Importantly, muscular strength was assessed twice during baseline; once in the first week, and again in the second week of baseline assessments. This was done to ensure the results of the strength testing were accurate.

2.4. Intervention protocols

2.4.1. Resistance training

The resistance training intervention consisted of three, 30-min sessions per week for three weeks (i.e., nine total sessions). The intervention was designed to be the same length as other research, which has shown aerobic exercise to improve sleep quality in as little as three weeks (Kalak et al., 2012). Each 30-min session included a 5-min warm up on a stationary bicycle, five resistance training exercises (i.e., squat, bench press, pulldown, overhead press, and biceps curl) done over the course of 20 min, and a 5-min cool down on a stationary bicycle. Two to three sets were performed of each exercise, at a load equal to the greatest 8-RM achieved during the two baseline assessments. Importantly, participants were instructed to perform each exercise to momentary muscular failure to ensure the exercise intensity was high (Arent, Landers, Matt, & Etnier, 2005). Prior research has shown that the strongest relationship between exercise, sleep, and PTSD is with high intensity exercise (Whitworth, Craft, Dunsiger, & Ciccolo, 2017a). Additionally, participants rested for 60–90 s between sets and exercises. For safety, all training sessions were one on one, supervised by a certified personal trainer, and sessions were only conducted on nonconsecutive days (e.g., Monday, Wednesday, and Friday) to ensure proper recovery.

2.4.2. Attention control

In each of the nine, 30-min sessions, participants learned about various topics unrelated to exercise, trauma, or PTSD (e.g., nutrition, human anatomy, the universe) through videos and handouts. To be consistent with the experiences of the resistance training group, sessions were one on one, and appointments were only scheduled on nonconsecutive days (e.g., Monday, Wednesday, and Friday).

2.5. Statistical analysis

Descriptive statistics are reported as mean (standard deviation) for continuous data, and percentages for categorical data. Mean between-group differences at follow-up were analyzed using analysis of covariance. Specifically, a group variable (i.e., resistance training or control) was assigned as the independent variable, and follow-up scores of the variables of interest (i.e., sleep quality, PTSD, anxiety, and depression symptoms) were assigned as the dependent variables, while controlling for the baseline scores of these variables. Statistical significance was set *a priori* at $p < 0.05$, and effect size estimates were calculated using Cohen's *d*. Regarding sample size, we aimed to randomize at least 10 participants per group to provide estimates of the intervention effect size and variance.

3. Results

A total of 211 individuals were screened by phone. Of these, 22 were fully eligible and randomized into the study. Fig. 1 details the participant flow through the study from initial screening to analysis. The mean age of the randomized sample was 33.0 years (SD = 13.3), 81.8% were women, and 77.3% identified as a racial minority. Additionally, the average total PDS5 score at baseline was 41.0 (SD = 9.5), and scores for the intrusion, avoidance behaviors, mood and cognitions, and hyperarousal symptom clusters were: 9.7 (SD = 3.7), 5.2 (SD = 2.0), 14.8 (SD = 4.6), and 11.3 (SD = 5.4), respectively. Participants also reported an average of 3.9 (SD = 1.8) traumatic events. The most commonly reported traumas were child abuse (59.1%), serious accidents (54.5%), and sexual assault (50.0%). There were no significant between group differences for any variable at baseline. Baseline descriptive characteristics of the sample divided by group can be seen in Table 1 and a summary of the participants' trauma history are presented in Table 2.

Regarding protocol adherence the resistance training and control groups attended 8.4 (SD = 2.1), and 8.3 (SD = 2.1) sessions, respectively. Session attendance did not significantly differ between groups, ensuring a similar dose of attention between groups. For the resistance training group, the mean session RPE was 6.6 (SD = 1.2), which is consistent with high intensity exercise (Day, McGuigan, Brice, & Foster, 2004; Sweet, Foster, McGuigan, & Brice, 2004). In addition to high adherence to the intervention by both groups, the resistance training sessions were well tolerated, with no reported adverse events. As a manipulation check, changes in muscular strength were assessed over the course of the intervention. The resistance training group significantly improved in muscular strength relative to the control for the squat $F(1, 16) = 11.33$, $p < 0.01$, bench press $F(1, 16) = 21.59$, $p < 0.01$, pulldown $F(1, 16) = 7.65$, $p = 0.01$, overhead press $F(1, 16) = 49.25$, $p < 0.01$, and biceps curl $F(1, 16) = 23.44$, $p < 0.01$. See Table 3 for mean changes and effect size estimates for muscular strength presented by group.

3.1. Resistance training vs. control for global sleep quality

Examination of the total PSQI score revealed a significant difference for group at follow-up $F(1, 16) = 12.04$, $p < 0.01$, such that the resistance training group reported significantly better global sleep quality

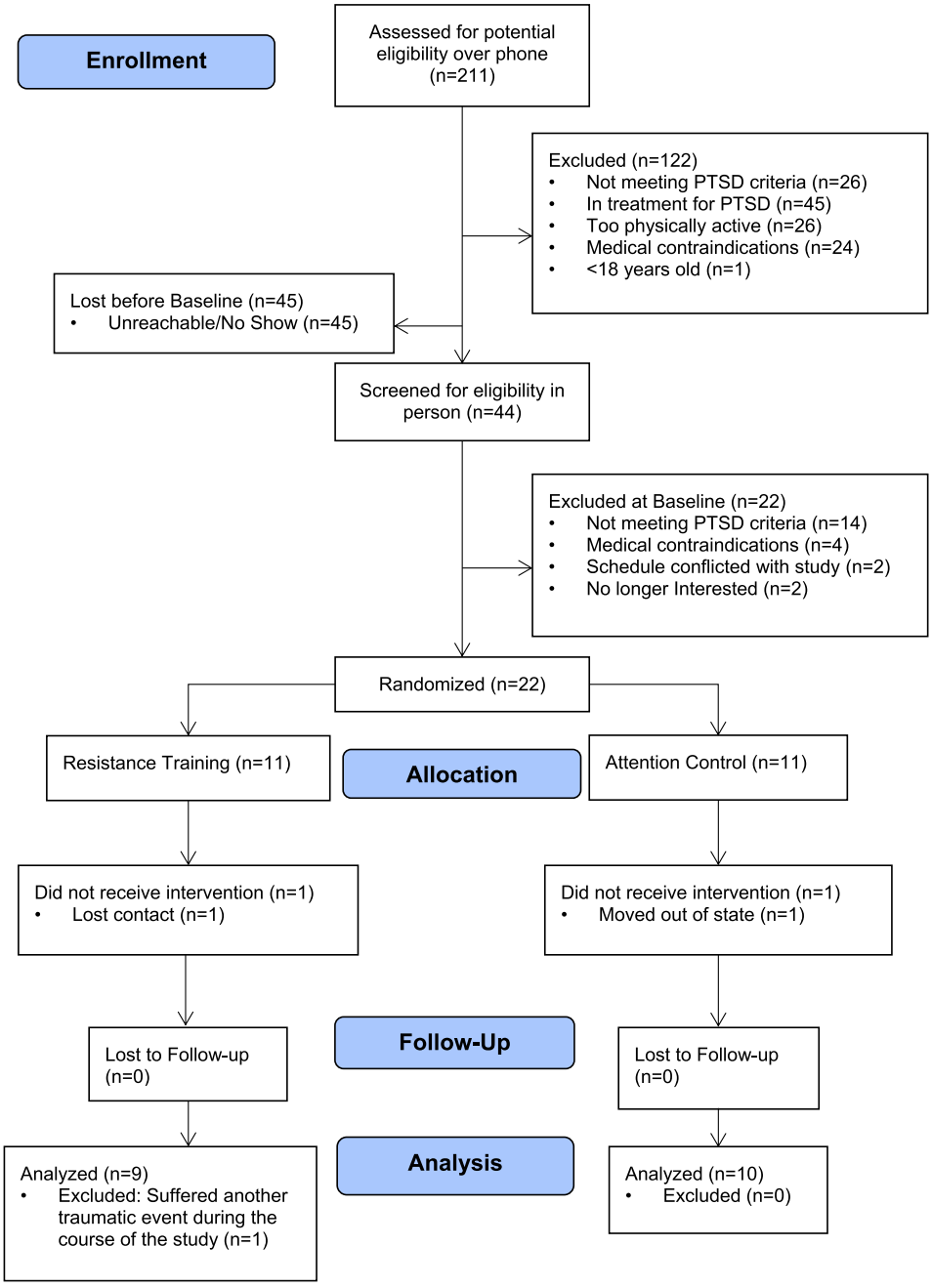

Fig. 1. Study flow.

relative to the control. Similarly, when examining the PSQI subscales, the resistance training group reported significantly improved sleep latency at follow-up relative to the control $F(1, 16) = 13.45$, $p < 0.01$. However, there were no observed group differences for the remaining subscales: sleep duration $F(1, 16) = 2.87$, $p = 0.11$, sleep disturbances $F(1, 16) = 0.31$, $p = 0.58$, daily dysfunction due to fatigue $F(1, 16) = 0.90$, $p = 0.36$, perceived sleep quality $F(1, 16) = 3.29$, $p = 0.09$, sleep medication usage $F(1, 16) = 0.33$, $p = 0.57$, and sleep efficiency $F(1, 16) = 0.88$, $p = 0.36$. See Table 4 for mean changes and effect size estimates for the PSQI presented by group.

3.2. Resistance training vs. control for PTSD, anxiety, and depression

When comparing the follow-up scores for the PDS5, there were no observed group differences for total PTSD symptoms $F(1, 17) = 0.01$, $p = 0.91$, intrusion symptoms $F(1, 17) < 0.01$, $p = 0.98$, avoidance symptoms $F(1, 17) = 0.63$, $p = 0.49$, mood and cognitive symptoms $F(1, 17) = 0.02$, $p = 0.91$, and hyperarousal symptoms $F(1, 17) = 0.21$, $p = 0.67$. However, there was a significant group difference for anxiety symptoms as measured by the STAI $F(1, 17) = 5.45$, $p = 0.03$, such that the resistance training group reported significantly lower anxiety symptoms at follow-up as compared to the control. Finally, there was no significant group differences in CESD score at follow-up $F(1, 17) = 1.98$, $p = 0.18$. See Table 5 for mean changes and effect size estimates for PTSD, anxiety, and depression symptoms presented by group.

4. Discussion

This pilot study sought to explore the feasibility and effects of a brief resistance training intervention on sleep quality, PTSD, anxiety, and depression symptoms in a sample of non-treatment seeking adults who

Table 1
Sample characteristics (n = 22).

	Intervention (n = 11)	Control (n = 11)
	Mean (standard deviation)	
Age	33.8 (11.1)	32.1 (15.6)
Body Mass Index	27.5 (11.4)	27.4 (4.6)
Muscular Strength, 8-RM		
Squat, lbs.	110.0 (45.6)	115.5 (58.0)
Bench press, lbs.	32.7 (40.5)	30.9 (30.2)
Pulldown, lbs.	52.7 (19.5)	53.6 (22.4)
Overhead press, lbs.	35.0 (11.2)	31.8 (11.2)
Biceps curl, lbs.	33.2 (10.8)	31.4 (13.6)
	n (%)	
Gender (women)	9 (81.8%)	9 (81.8%)
Race		
White	3 (27.3%)	2 (18.2%)
Black or African American	4 (36.4%)	4 (36.4%)
Asian	2 (18.2%)	4 (36.4%)
Other	2 (18.2%)	1 (9.1%)
Education		
High school or less	2 (18.2%)	2 (18.2%)
Some college/vocational school	4 (36.4%)	1 (9.1%)
Completed college/vocational school	5 (45.4%)	8 (72.7%)
Employment status		
Employed at least part time	5 (45.4%)	6 (54.5%)
Unemployed	4 (36.4%)	2 (18.2%)
Other	2 (18.2%)	3 (27.3%)
Household Income		
≤$15,000	2 (18.2%)	3 (27.3%)
$15,001-$25,000	3 (27.3%)	0 (0.0%)
$25,001-$40,000	1 (9.1%)	0 (0.0%)
$40,001-$60,000	2 (18.2%)	1 (9.1%)
> $60,001	0 (0.0%)	2 (18.2%)
Do not know	3 (27.3%)	4 (36.4%)

RM = Repetition Maximum; lbs. = pounds.

Table 2
Trauma exposure history (n = 22).

Trauma type	n (%)
Serious, life threatening illness	6 (27.3%)
Physical assault	10 (45.5%)
Sexual assault	11 (50.0%)
Military combat	1 (4.5%)
Child abuse	13 (59.1%)
Serious accident	12 (54.5%)
Natural disaster	4 (18.2%)
Other	6 (27.3%)

screened positive for PTSD. The key findings of this study suggest that three weeks of high intensity resistance training is a safe, acceptable, and feasible intervention in this sample. Additionally, the results demonstrated large significant improvements in global sleep quality and medium significant reductions in anxiety symptoms for the resistance training group relative to the attention-control condition.

Relating to feasibility, of the 211 individuals initially screened by telephone, 10.4% were enrolled in the study. The majority (66.4%) of the callers were excluded because they did not meet the eligibility criteria (e.g., not screening positive for PTSD). Among those who were eligible, 23.2% reported being too busy, uninterested, or were not reachable, suggesting that the study and/or intervention was not universally appealing (See Fig. 1). Prior research has reported similar proportions of non-interest in individuals with insomnia and co-occurring mental illness (Gutner, Pedersen, & Drummond, 2018). Of the participants who received the resistance training intervention all 10 completed the study with perfect attendance, supporting the feasibility of the intervention. The results also suggest that high intensity resistance training is safe, as there were no adverse events reported during the course of the study.

In addition to evidence of feasibility, the results indicate that the intervention had beneficial effects on different components of sleep. For instance, a closer inspection of the PSQI subscales revealed that resistance training had the largest beneficial effect on sleep latency, indicating that the time taken to transition from wakefulness to sleep was meaningfully decreased. Resistance training also produced non-significant medium sized beneficial effects on daily dysfunction due to drowsiness, perceived sleep quality, sleep medication usage, and sleep efficiency. These findings are very encouraging given that poor sleep quality is a common issue for individuals with PTSD, and even for individuals who have undergone successful treatment for PTSD (Pruiksma et al., 2016). Also, these results may have further clinical importance, as prior observational research has hypothesized that exercise-related changes in sleep quality may indirectly benefit PTSD (Babson et al., 2015; Talbot, Neylan, Metzler, & Cohen, 2014; Whitworth, Craft, et al., 2017a).

Regarding PTSD symptoms, this study did not demonstrate any significant group differences in PTSD symptoms as measured by the PDS5. Overall, there were similar beneficial effects reported by both groups. This was unexpected, given the known beneficial effects of aerobic exercise and combination training reported in previous research (Powers et al., 2015; Rosenbaum et al., 2015). A key difference may be the brief duration of the present intervention (i.e., three weeks) and the chronic nature of PTSD. It is possible that a longer duration study (e.g., 12-weeks) is required before the direct and/or indirect effects of resistance training on PTSD can manifest relative to a control.

This study also examined the effects of resistance training on anxiety and depression symptoms. For anxiety symptoms, the resistance training condition produced a significant medium effect size reduction in anxiety symptoms relative to the control. In contrast, the intervention effects on depression symptoms were small and did not reach significance. However, the significant anxiolytic effect reported by the resistance training group is noteworthy because, like poor sleep quality, co-occurring anxiety symptoms can worsen PTSD. Thus, by reducing anxiety through resistance training or other forms of exercise, it may be possible to produce a net therapeutic effect on PTSD. As such, further investigations of the effects of resistance training on co-occurring

Table 3
Group comparison and effect size estimates for muscular strength.

	RT, Mean (SD)		*d*	Control, Mean (SD)		*d*
	Baseline	Follow-up		Baseline	Follow-up	
Squat	117.8 (47.1)	151.1 (55.3)	0.65*	114.0 (61.0)	115.0 (70.5)	0.02
Bench press	33.9 (45.0)	45.6 (46.7)	0.26*	32.0 (31.6)	35.0 (30.7)	0.10
Pulldown	51.1 (20.9)	61.1 (21.9)	0.47*	54.0 (23.5)	57.2 (21.7)	0.14
Overhead press	35.6 (12.4)	45.0 (12.7)	0.75*	32.5 (11.6)	33.9 (11.4)	0.12
Biceps curl	32.2 (11.2)	39.4 (10.4)	0.67*	31.5 (14.3)	32.8 (14.2)	0.09

RT = Resistance training; SD = standard deviation; *d* = Cohen's *d*. *denotes significant group differences at $p < 0.05$.

Table 4
Group comparison and effect size estimates for global sleep quality.

	RT, Mean (SD)		*d*	Control, Mean (SD)		*d*
	Baseline	Follow-up		Baseline	Follow-up	
PSQI Total	11.3 (4.9)	7.1 (4.1)	−0.93*	7.8 (2.5)	8.4 (2.9)	0.22
Sleep Duration	1.6 (1.3)	1.1 (1.3)	−0.39	0.9 (0.9)	1.0 (1.0)	0.11
Sleep Disturbances	1.6 (0.7)	1.6 (0.9)	0.0	1.4 (0.5)	1.3 (0.5)	−0.20
Sleep Latency	2.4 (0.7)	1.1 (0.9)	−1.61*	1.7 (1.1)	2.0 (1.1)	0.27
Daily Dysfunction	1.7 (1.1)	1.1 (0.8)	−0.62	1.2 (1.1)	1.3 (0.7)	0.11
Perceived Quality	2.0 (1.0)	1.4 (0.9)	−0.63	1.2 (0.4)	1.8 (0.7)	1.05
Sleep Medications	1.0 (1.2)	0.3 (1.0)	−0.63	0.2 (0.4)	0.2 (0.4)	0.0
Sleep Efficiency	1.1 (1.2)	0.4 (0.9)	−0.66	0.9 (0.8)	0.8 (1.1)	−0.10

RT = Resistance training; SD = standard deviation; *d* = Cohen's *d*; PSQI = Pittsburgh Sleep Quality Index. Negative effect sizes represent improvements in sleep. *denotes significant group differences at $p < 0.05$.

Table 5
Group comparison and effect size estimates for PTSD, anxiety, and depression symptoms.

	RT, Mean (SD)		*d*	Control, Mean (SD)		*d*
	Baseline	Follow-up		Baseline	Follow-up	
Total PDS5	37.8 (10.7)	25.6 (16.7)	−0.87	43.3 (8.8)	30.9 (15.0)	−1.00
Re-experiencing	9.1 (4.9)	6.0 (4.7)	−0.65	10.0 (3.1)	6.3 (2.8)	−1.25
Avoidance	4.8 (2.3)	2.7 (2.1)	−0.95	5.5 (1.8)	3.7 (2.1)	−0.92
Mood/cognitive	13.6 (4.4)	9.6 (6.4)	−0.73	15.0 (5.1)	10.5 (7.6)	−0.70
Hyperarousal	10.3 (6.8)	7.3 (7.2)	−0.43	12.8 (3.0)	10.4 (4.9)	−0.59
STAI	54.7 (11.5)	46.2 (13.6)	−0.68*	48.3 (11.8)	48.8 (13.8)	0.04
CESD	15.1 (6.8)	11.0 (7.0)	−0.49	13.2 (3.9)	13.6 (8.0)	0.06

PTSD = Posttraumatic stress disorder; RT = Resistance training; SD = standard deviation; *d* = Cohen's *d*; PDS5 = Posttraumatic Diagnostic Scale for DSM-5; STAI = State-Trait Anxiety Inventory; CESD = Center for the Epidemiological Studies of Depression Short Form. Negative effect sizes represent improvements in PTSD, anxiety, and depression. *denotes significant group differences at $p < 0.05$.

anxiety and PTSD are warranted.

In addition to the above findings, this study has several notable strengths that add further context to the results. First, to our knowledge, this is the only study in the field to use a randomized time-matched attention-controlled design. This is a notable strength, given the beneficial effect the attention control had on PTSD symptoms. It is possible that the time spent in contact with research staff and/or traveling to and from the study site (e.g., navigating public transportation) had a therapeutic effect, as individuals with PTSD often isolate themselves and avoid crowds or public spaces. Second, the mode of exercise examined in this study (i.e., resistance training) is currently underrepresented in not only PTSD research, but also in the overall field of exercise and mental health. As such, this study helps to fill an important gap in the literature. A third strength of this study is the target population of non-treatment seeking individuals. Specifically, this study recruited individuals who were not currently in, or seeking help through conventional treatment options (i.e., psychotherapy or medications). This is meaningful because there are large disparities between those receiving treatment for PTSD vs. those who need treatment (Elbogen et al., 2013). This study provides preliminary support that exercise may be an acceptable intervention for non-treatment seeking individuals who screen positive for PTSD.

Despite these strengths, there are some limitations worth considering. Perhaps the most significant limitation of the study is the is small sample size. This study aimed at assessing the feasibility of a novel intervention rather than conducting a fully powered trial. As such, the results of this study require verification by a larger fully powered randomized controlled trial. Another potential limitation of this study is the use of a self-report measure to screen for PTSD (i.e., PDS5) rather than a clinical interview to determine the diagnostic status of the participants. This makes it impossible to determine if all the participants met a clinical level of PTSD. Despite this limitation, the PDS5 is a reliable and valid screening tool for PTSD (Foa et al., 2015).

5. Conclusion

Nine sessions of high intensity resistance training over the course of three weeks can improve sleep quality and reduce anxiety relative to a control group. These findings may have clinical relevance, considering the common co-occurrence of insomnia and anxiety with PTSD and their profound negative impact on both physical and mental health. This study also suggests that resistance training is a safe and feasible intervention for individuals who screen positive for PTSD. However, while promising, the results of this study are preliminary and additional fully powered trials are needed for verification. Future studies are also needed to continue to examine the effects of resistance training on PTSD and its co-occurring conditions, as the effects of resistance training on PTSD are largely unexplored. Finally, research testing and cataloging the effects of exercise dose (i.e., intensity, frequency, and duration) on sleep and PTSD will be necessary before any optimal exercise prescription recommendations can be made.

Conflicts of interest

The authors have no conflict of interest to disclose.

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