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Self-reported exercise frequency and PTSD: results from the National Health and Resilience in Veterans Study

Adams TG, Forte J, Fogle BM, Southwick SM, Pietrzak RH. Self-reported exercise frequency and PTSD: results from the National Health and Resilience in Veterans Study.

Objective: Physical exercise may serve as a protective factor for posttraumatic stress disorder (PTSD), but little is known about whether physical exercise is associated with PTSD in population-based samples of military veterans.
Methods: We analyzed cross-sectional data on the relation between self-reported physical exercise frequency and the prevalence of probable PTSD in a nationally representative sample of 2832 U.S. military veterans who participated in the National Health and Resilience in Veterans Study.
Results: A "U-shaped" association best explained the relation between self-reported exercise frequency and the prevalence of probable PTSD. Compared to veterans without probable PTSD, those with probable PTSD were nearly twice as likely to report no weekly exercise (52.3% vs. 29.3%) or daily (7 days/week) exercise (15.2% vs. 8.5%) and were nearly half as likely to report exercising a median of 3.5 days/week (32.6% vs. 62.1%). No exercise was associated with greater severity of emotional numbing and lower severity of anxious arousal symptoms, while daily exercise was associated with greater severity of re-experiencing symptoms.
Conclusions: Results of this study suggest a "U-shaped" association between self-reported exercise frequency and the prevalence of probable PTSD among U.S. veterans. Veterans with probable PTSD were more likely than those without probable PTSD to report not exercising at all or exercising every day and were less likely to report exercising 1–6 days per week. Clinical implications of these findings are discussed.

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Significant outcomes and Limitations

- Veterans who reported exercising 3 or more days per week were less likely to screen positive for PTSD than veterans who reported exercising less than 3 days per week.
- Veterans who screened positive for PTSD were nearly twice as likely as those who screened negative for PTSD to report no weekly exercise or daily exercise.
- Veterans who reported at least some weekly exercise (1–6 days per week) were least likely to screen positive for PTSD.
- Results are based on cross-sectional data, so causal inferences cannot be made.
- A single item was used to assess exercise frequency, which may limit generalizability of findings.
- Future work should utilize experimental or longitudinal designs, and more comprehensive assessments of exercise frequency, intensity, and types to better characterize the association between exercise and PTSD.

Introduction

Nearly 70% of the U.S. general adult population will experience trauma in their lifetime, 6.1% of whom will meet diagnostic criteria for posttraumatic stress disorder (PTSD) (1). Multiple studies have observed a "dose-response" relation between trauma exposure and PTSD symptoms, a fact that may partly explain why the prevalence of PTSD is higher among U.S. military veterans (6.9%), who are likely to be exposed to more trauma, including combat exposure, than their civilian counterparts (2).

While efficacious pharmacological and psychosocial treatments exist for PTSD, they may be less efficacious among U.S. veterans (3–5). Modest treatment effects among veterans are due, in part, to high rates of "treatment-resistant PTSD," psychiatric comorbidities, and possible gender effects (6). Thus, there is a clear need to improve existing treatments and develop alternative treatments for PTSD, especially for veterans (5, 6). Moreover, it is important to develop prevention and treatment approaches that may help mitigate risk for the development of PTSD through the promotion of factors that can help bolster resilience and recovery. This is particularly important for military veterans, given their higher rates of trauma exposure and PTSD (2).

Physical exercise is one promising behavioral strategy that has been explored for its potential to reduce PTSD symptoms and promote recovery and resilience. Physical exercise has been shown to convey significant benefits to mental health (7, 8) and a growing body of literature has demonstrated an inverse relation between exercise and PTSD symptoms (9–12). A recent narrative review of 19 empirical studies concluded that increased levels of aerobic exercise—"...a subcategory of physical activity that is planned, structured, repetitive, and intended to improve and maintain physical fitness," (p. 2)—was negatively associated with PTSD symptoms (13). This conclusion was based on research characterizing the cross-sectional association between exercise and PTSD symptoms, as well as studies examining the effects of aerobic exercise as a stand-alone or adjunctive treatment.

Interventional studies examining the effects of exercise on PTSD symptoms among military veterans have yielded consistent results. Each of the three published studies reported that structured exercise as a stand-alone or adjunctive treatment led to reductions in PTSD symptoms (14–17). Although promising, these were open-label (14, 16) and wait-list controlled (15, 17) studies and, with the exception of one study (14), were limited by small sample sizes.

Extant observational studies on the association between exercise frequency and PTSD symptoms among military veteran samples have reported mixed findings (14, 18–23). Two studies have reported that military veterans with PTSD were significantly less likely to report engaging in weekly exercise than those without PTSD (24, 25). One longitudinal study reported that 20 min of vigorous exercise 2 or more times per week prospectively predicted decreased odds of developing PTSD and of having persistent PTSD symptoms at follow-up (26). These latter findings suggest that even limited frequency of exercise may promote recovery or may even serve to reduce PTSD symptoms among military veterans. To date, however, at least four observational studies have failed to detect significant associations between PTSD symptoms and exercise frequency among military veterans (20, 27–29).

Most cross-sectional studies on exercise and PTSD have reported small effect sizes and have depended on relatively small or non-representative samples. Moreover, while most previous work has evaluated linear or binary associations between exercise and PTSD, emerging research has demonstrated non-linear associations between exercise frequency and mental health outcomes in the general population (30). Specifically, analysis of data from more than 1.2 million adults revealed that those who reported exercising three-to-five times per week reported significantly fewer days of poor mental health than those who reported exercising zero-to-two times per week and six-to-seven days per week (30). It is therefore possible that some of the aforementioned null associations between exercise frequency and PTSD may have resulted from lack of power, homogenous samples, or analytic strategies that masked nuanced and non-linear effects. Additional research is needed to clarify the linear and non-linear nature of the association between exercise frequency and PTSD symptoms among population-based, nationally representative, and large samples of military veterans.

Previously reported null findings on exercise and PTSD may have also been influenced by the heterogeneity of the PTSD phenotype. Extant research suggests that exercise may be most strongly associated with the hyperarousal (11, 12, 14, 27, 31) and avoidance and numbing (12, 31) symptoms. Although exercise may reduce symptoms of avoidance, emotional numbing, and hyperarousal, it is also possible that greater severity of these symptoms may be linked to reduced engagement in physical exercise in attempt to avoid state-dependent physiological arousal, which can trigger intrusive trauma-related thoughts (32,

33). Similarly, greater severity of emotional numbing symptoms may be associated with less frequent exercise due to insufficient motivation or a lack of experiential pleasure derived from exercising (34). Although it is yet to be examined, it is also reasonable to speculate that re-experiencing symptoms may be associated with more excessive engagement in physical exercise, perhaps as a form of "active avoidance" to distract/distance oneself from trauma-related thoughts and feelings (35, 36).

Aims of the study

To address the aforementioned gaps in the literature, the present study aimed to: (i) Examine the association between self-report frequency of physical exercise and prevalence of probable PTSD in a large, nationally representative sample of U.S. military veterans; (ii) Evaluate the non-linear associations between the "dose" of exercise frequency and prevalence of probable PTSD; and (iii) Examine differential associations between PTSD symptom clusters and frequency of engagement in physical exercise. Based on prior work, we hypothesized that reports of more frequent engagement in physical exercise would be associated with lower prevalence of probable PTSD, but that this effect would be nuanced such that veterans who reportedly engaged in an intermediate amount of exercise (e.g., median of 3 days per week) would have lower prevalence of probable PTSD compared to those who reported no exercise (i.e., 0 days per week) or daily exercise (i.e., 7 days per week). We further expected that greater severity of emotional numbing, avoidance, and hyperarousal symptoms would be associated with greater likelihood of reporting no engagement in exercise, while greater severity of re-experiencing symptoms would be associated with greater likelihood of reporting engagement in daily exercise.

Methods

Procedures

Data were analyzed from the National Health and Resilience in Veterans Study (NHRVS), which surveyed a nationally representative sample of U.S. military veterans. The NHRVS sample was recruited between October and December 2011 from a survey research panel of over 50,000 U.S. households to complete a web-based survey. All procedures were reviewed and approved by the Human Subjects Subcommittee of VA Connecticut Healthcare System. Study procedures conform with recognized ethical standards of the Declaration of Helsinki and the US Federal Policy for the Protection of Human Subjects. All participants provided IRB-approved informed consent prior to completing the survey. Post-stratification weights based on demographic distributions of U.S. veterans from contemporaneous U.S. Census data were applied to the sample to promote generalizability of results to the entire population of U.S. veterans. Additional details regarding the NHRVS sample are available elsewhere (37).

Assessments

Physical exercise. The number of days that participants typically exercised per week (0–7) was assessed using a question from a self-report activities inventory: "How many days per week do you typically engage in the following activities: sports/exercise?" (response options: 0–7) (38).

The *Trauma History Screen* (THS) was administered to assess lifetime exposure to 14 potentially traumatic events; (39) in the NHRVS, life-threatening illness or injury was additionally assessed. Events were summed to yield a measure of cumulative lifetime trauma burden.

The PTSD Checklist-Specific Stressor Version (PCL-S) was used to assess PTSD symptoms. The PCL-S is a 17-item self-report instrument that uses a 1-to-5 Likert-type scale ranging from "not at all" to "extremely" to assess the extent to which an individual is bothered by each PTSD symptom. In this NHRVS, PTSD symptoms were assessed in response to each participant's "worst trauma" from those that they endorsed on the THS. As such, the PCL-S was administered to all participants who endorsed exposure to at least one traumatic event on the THS and a score of 17 was imputed for all participants who did not endorse at least one potentially traumatic event. Probable PTSD diagnosis was assessed using a cutoff score of $\geq$50 (40). PTSD symptom clusters were computed by summing individual PCL-S items that corresponded to the 5-factor model of DSM-IV PTSD symptoms, which includes re-experiencing (items 1–5), avoidance (items 6–7), emotional numbing (items 8–12), dysphoric arousal (items 13–15), and anxious arousal (items 16–17) symptoms (41). See Figure S1 for distribution of PCL-S scores in the present sample.

Single-item questions were used to assess a range of sociodemographic and military characteristics. Disability in activities of daily living (ADL), which was adjusted for in analyses to control for the effect of physical disability on exercise frequency, was assessed with a single item: "At the present time, do you need help from another person to do the following? (e.g., bathe; walk around your home

or apartment; get dressed; get in and out of chair)." (42).

Participants

The study sample included 2,832 veterans, of whom 2,441 reported exposure to at least one lifetime potentially traumatic event on the THS and completed the PCL-S; a minimum PCL-S score of 17 was imputed for the remaining 391 veterans. A total 10.0% (n = 277) of the sample were women, 76.9% were White, non-Hispanic, 8.2% were Hispanic, 70.6% (n = 1953) of veterans were married/partnered, 45.7% (n = 1262) reported an annual household income of $60 000 or more, 68.6% ($n$ = 1897) reported some college education or higher, and 3.7% (n = 103) reported at least one ADL disability. A total 4.8% (n = 132) of the sample screened positive for PTSD (Table 1).

Data analytic strategy

Multiple imputation using chained equations was used to impute missing PCL-S item values prior to analysis. Missing values were only imputed for veterans who were missing less than 5% data and were not imputed for single-item questions, including the exercise frequency, sociodemographic, and ADL disability questions analyzed in the present study. Alpha was set to 0.01 for all analyses to reduce the likelihood of Type I error.

A minimum of 3 days of exercise per week is recommended to improve cardiorespiratory health (43). Accordingly, a series of chi-square analyses and t tests were conducted to compare veterans who reported exercising less than three days a week to those who reported exercising three or more days a week with respect to sociodemographic and military variables, ADL disability, number of lifetime potentially traumatic events, and prevalence of probable PTSD.

A series of multivariable logistic regression analyses were conducted to characterize the associations between exercise frequency and PTSD symptoms. Covariates were the same for all logistic regressions and included ADL disability, number of lifetime potentially traumatic events, and sociodemographic variables that differed by PTSD status in bivariate analyses (see below): gender, education, income, race, and ethnicity.

First, a hierarchical logistic regression was conducted to compare the prevalence of probable PTSD between those who reported exercising the recommended frequency (3 or more days per week) and those who reported exercising less than the recommended frequency; covariates were entered in the first block and exercise frequency (<3 [0] vs. ≥3 [1] days per week) was entered in a second block.

Second, a quadratic logistic regression, with reported exercise frequency (0–7 days per week) modeled as linear and quadratic variables, was conducted to examine whether the relation between exercise frequency and probable PTSD was explained by a non-linear (e.g., U-shaped) association. Covariates were entered in the first block, the linear (0–7) effects of exercise in the second block, and the quadratic (0–49) effects of exercise in the third block.

Third, a multinomial logistic regression was conducted to examine associations between PTSD symptom clusters and frequency of exercise. Based on the results of the quadratic logistic regression model, exercise frequency was modeled as a three-category variable (0, 1–6, and 7 days/week) in the multinomial regression, which was regressed onto

Table 1. Sociodemographic and psychiatric differences between veterans (total weighted n = 2764) who self-report that they exercise 3 or more days per week and veterans who report less frequent exercise (fewer than 3 days per week)

	Exercise < 3 Days/Week n (weighted %) or weighted M(SD)	Exercise ≥ 3 Days/Week n (weighted %) or weighted M(SD)	Test of difference
Total Sample	1458 (52.7%)	1306 (47.3%)	
Age	59.4 (14.9)	60.1 (15.5)	t = 1.21, P = 0.23
Female gender	120 (8.2%)	157 (12.0%)	X^2 = 11.02, P < 0.001
White race	1098 (75.4%)	1028 (78.7%)	X^2 = 11.20, P < 0.05
Hispanic ethnicity	143 (9.8%)	83 (6.4%)	X^2 = 10.94, P = 0.001
Some college or higher education	868 (31.4%)	1029 (37.2%)	X^2 = 118.66, P < 0.001
Married/partnered	1025 (70.3%)	928 (71.0%)	X^2 = 5.79, P = 0.33
Income>$60K	590 (40.5%)	672 (51.5%)	X^2 = 96.62, P < 0.001
Currently employed	627 (43%)	533 (40.8%)	X^2 = 1.36, P = 0.24
ADL disability	75 (5.1%)	28 (2.1%)	X^2 = 17.28, P < 0.001
Years of service	7.0 (7.3)	7.1 (7.5)	t = 0.54, P = 0.59
Combat veteran	515 (35.5%)	447 (34.3%)	X^2 = 0.47, P = 0.50
Number of traumas	3.4 (3.0)	3.4 (2.7)	t = 0.76, P = 0.45
PCL-S ≥ 50	95 (6.5%)	37 (2.8%)	X^2 = 20.55, P < 0.001

five PTSD symptom clusters—re-experiencing, avoidance, emotional numbing, dysphoric arousal, and anxious arousal—with intermediate exercise frequency (i.e., 1–6 days/week, median = 3.5 days) entered as the reference category. Covariates were entered simultaneous with PTSD symptom cluster scores.

Results

One hundred thirty-two veterans (4.8%) screened positive for probable PTSD (PCL-S $\geq$ 50). As shown in Table 1, relative to veterans who exercised less than three days per week, those who exercised three or more days per week were significantly ($p \leq .01$) more likely to be female, non-Hispanic, and to report greater educational attainment and a higher household income. Those who exercised three or more days per week were also more likely to be Caucasian, but this effect was only significant at the $P < 0.05$ level. Veterans who exercised less than three days per week were also more likely to report at least one ADL disability than those who exercised three or more days per week. No significant differences were observed among other sociodemographic or military variables. Veterans who exercised less than three days per week were significantly more likely to screen positive for probable PTSD than those who exercised three or more days per week. These exercise groups did not differ with respect to number of lifetime potentially traumatic events ($P = 0.45$) or combat deployments ($P = 0.66$).

Of the covariates used in the logistic regression models, race, ADL disability status, and number of lifetime traumas were the only variables that were independently associated with a probable PTSD diagnosis ($ps \leq 0.01$; Table 2); Non-White veterans and disabled veterans were more likely to report probable PTSD than White, non-Hispanic, non-disabled veterans, and the prevalence of probable PTSD increased as the number of lifetime traumas increased. Collectively, covariates explained 30% of the variance in probable PTSD (Nagelkerke $R^2 = 0.30$).

Exercising three or more days per week was associated with an estimated 49% lower odds of probable PTSD ($P < 0.01$, 95% CI = 0.21–0.77) after adjustment for covariates. Though statistically significant, the effect size of exercise frequency (0–2 days/week vs. $\geq$3 days/week) was small, Nagelkerke $R^2 = 0.31$ ($R^2\Delta = 0.01$).

As shown in Table 2, quadratic logistic regression revealed that the linear effect of exercise (modeled as 0–7 days/week) on probable PTSD was not significant ($P = 0.25$), but the quadratic effect (modeled as 0–49 days/week) was significant ($P \leq 0.001$) after adjusting for covariates. Though statistically significant, the effects size of curvilinear exercise frequency was small, Nagelkerke $R^2 = 0.32$ ($R^2\Delta = 0.02$). As shown in Fig. 1, no exercise (zero days per week) and daily exercise (7 days per week) were associated with the highest prevalence of probable PTSD, while 1–6 days per week of exercise (median 3 days/week) was associated with lower rates of probable PTSD.

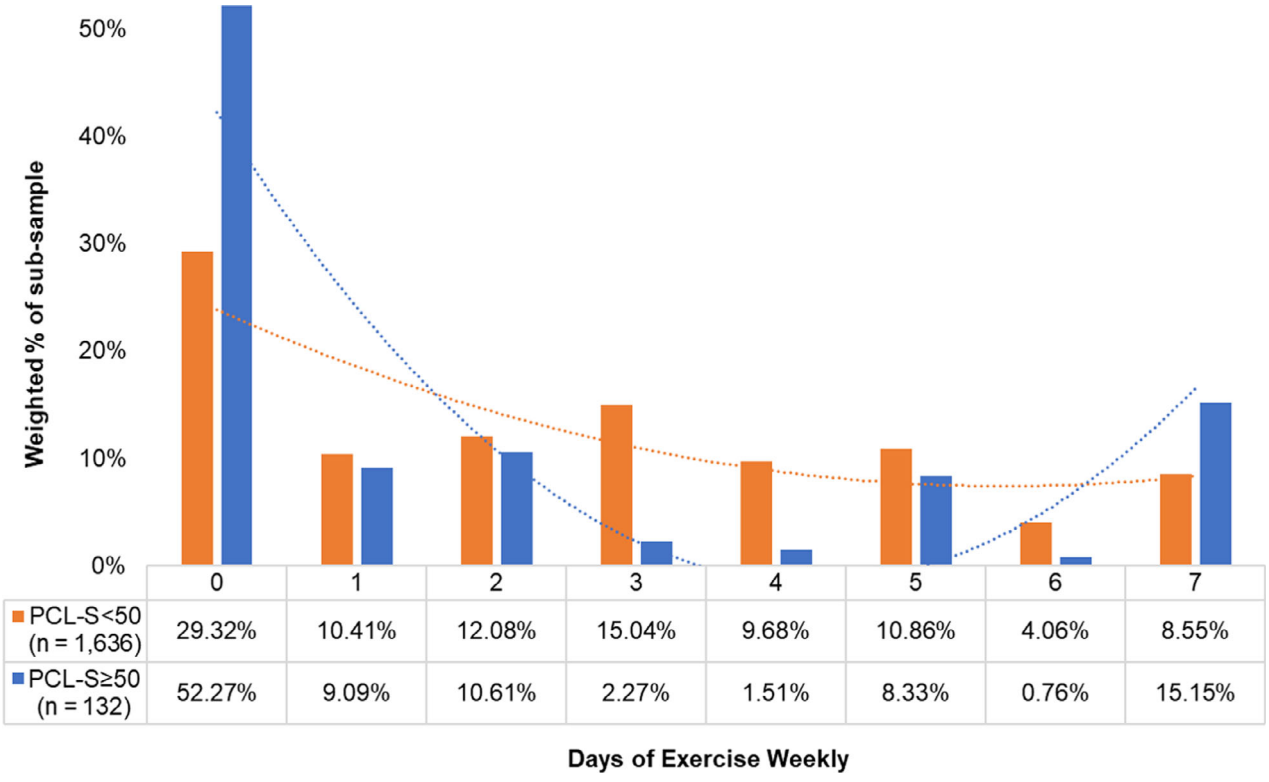
Table 2. Logistic regression analyses examining the associations between self-reported exercise frequency (days per week) and probable PTSD (PCL-S $\geq$ 50). Covariates were entered in the first block and exercise frequency was entered in subsequent blocks

	Wald	OR (95%CI)
Covariates†		
Block 1 ($R^2 = 0.30$)		
Gender	0.94, $P = 0.33$	0.72 (0.36–1.42)
Educational attainment	3.64, $P = 0.06$	0.65 (0.42–1.01)
Income	5.40, $P = 0.02$	0.59 (0.38–0.92)
Race	6.69, $P = 0.01$	1.87 (1.16–3.01)
Ethnicity	0.13, $P = 0.91$	0.96 (0.49–1.89)
ADL disability	17.80, $P < 0.001$	3.41 (1.93–6.02)
Sum Trauma	156.13, $P < 0.001$	1.47 (1.38–1.56)
Linear Logistic Regression		
Block 2 ($R^2\Delta = 0.01$)		
Exercise frequency (<3 [0] vs. ≥3 [1] days/week)	9.28, $P < 0.01$	0.51 (0.33–0.79)
Quadratic Logistic Regression		
Block 2 ($R^2\Delta = 0.00$)		
Exercise frequency linear (0–7 days/week)	1.35, $P = 0.25$	0.95 (0.87–1.04)
Block 3 ($R^2\Delta = 0.02$)		
Exercise frequency Quadratic (0–49)	19.92, $P < 0.001$	1.11 (1.06–1.16)

†The same covariates were entered for all regression equations; statistical values for all covariates were, therefore, identical for each equation. $R^2\Delta$ was calculated using Nagelkerke R^2.

Of the veterans who screened positive for PTSD, more than half ($n = 69$, 52.3%) reported no weekly exercise, while less than a third of the veterans who did not screen positive for PTSD reported no weekly exercise ($n = 772$, 29.3%). Similarly, veterans with probable PTSD were nearly twice as likely to report exercising seven days per week ($n = 20$, 15.2%) as veterans without probable PTSD ($n = 225$, 8.6%). Conversely, veterans with probable PTSD were approximately half as likely to report exercising 1–6 days per week ($n = 43$, 32.6%) compared to veterans without probable PTSD ($n = 1636$, 62.1%).

Results of a multinomial logistic regression examining the relation between PTSD symptom clusters and reported exercise frequency revealed that, after adjusting for covariates, no exercise (0 days/week) was associated with greater severity of emotional numbing ($P \leq 0.001$) and lower severity of anxious arousal ($P \leq 0.001$) compared



	0	1	2	3	4	5	6	7
PCL-S<50 (n = 1,636)	29.32%	10.41%	12.08%	15.04%	9.68%	10.86%	4.06%	8.55%
PCL-S≥50 (n = 132)	52.27%	9.09%	10.61%	2.27%	1.51%	8.33%	0.76%	15.15%

Fig 1. U-shaped association between weekly frequency of engagement in physical exercise and prevalence of probable PTSD in U.S. military veterans. Logistic regression with post-stratification weights and with self-reported exercise frequency modeled as linear (0–7) and quadratic (0–49) variables and sociodemographic covariates, revealed a significant ($P < 0.01$) positive quadratic effect of exercise on probable PTSD. Veterans with probable PTSD ($n = 132$) were approximately half as likely as those without probable PTSD ($n = 2633$) to report exercising 1–6 days per week but were nearly twice as likely to report not exercising at all or exercising every day. Those who reported exercising 1–6 days per week (group median = 3.5 days/week [$n = 1679$]) were significantly ($P < 0.05$) less likely to report probable PTSD (5.4%) compared to veterans who did not exercise at all (52.3%) or who exercised 7 days per week (15.2%). [Colour figure can be viewed at wileyonlinelibrary.com]

to intermediate exercise frequency (median 3.5 days/week [1–6 days/week]). Conversely, daily exercise (7 days/week) was associated with greater severity of re-experiencing symptoms ($P \leq 0.001$) compared to intermediate exercise frequency (median 3.5 days/week). No other PTSD symptoms clusters were significantly associated with reported exercise frequency ($ps > 0.04$). See Table 3 for results of this regression model.

Discussion

To our knowledge, this study is the first to examine the non-linear associations between self-reported frequency of physical exercise and PTSD in a nationally representative sample of U.S. military veterans. This study is also the first to report on the associations exercise frequency and specific PTSD symptom clusters in a nationally representative sample of U.S. military veterans. Results revealed that, after accounting for variance explained by sociodemographic variables, trauma exposure, and ADL disability, veterans who reported exercising three or more days per week were significantly less likely to screen positive for PTSD relative to veterans who reported exercising less than three days per week. This finding adds to a growing body of literature demonstrating that engagement in physical exercise is associated with lower prevalence of PTSD and related disorders (19). Several mechanisms may account for this association, including exercise-induced normalization of hypothalamic-pituitary adrenal axis function and inflammatory markers; enhanced neuroplasticity and cognitive function; and exposure and desensitization to internal arousal cues (13, 30). This association may also be due to PTSD negatively affecting one's ability and motivation to engage in physical exercise. This interpretation has important physical health implications for veterans, particularly those with significant PTSD symptoms, as lack of physical activity is associated with a broad range of adverse health outcomes, many of which are also associated with PTSD (13).

The associations between reported exercise frequency and prevalence of probable PTSD were

Table 3. Multinomial regression analysis examining the associations between self-reported exercise frequency on PTSD symptom clusters. Exercise frequency was modeled as a three-category variable (0 = 0 days/week [n = 841], 1 = 1–6 days/week [median = 3 days, n = 1679], and 2 = 7 days/week [n = 245]); 1–6 days/week was entered as the reference category

	Exercise frequency			
	0 vs. 1–6 days/week		7 vs. 1–6 days/week	
	Wald	OR (95%CI)	Wald	OR (95%CI)
Covariates				
Gender	6.96, $P < 0.01$	1.52 (1.14–2.07)	2.74, $P = 0.10$	1.50 (0.93–2.44)
Educational attainment	65.59, $P < 0.001$	2.18 (1.80–2.63)	2.13, $P = 0.15$	0.78 (0.55–1.09)
Income	20.02, $P < 0.001$	1.52 (1.27–1.83)	0.56, $P = 0.46$	1.11 (0.84–1.48)
Race	0.13, $P = 0.31$	0.88 (0.68–1.13)	0.25, $P = 0.62$	0.91 (0.62–1.33)
Ethnicity	8.76, $P < 0.01$	0.57 (0.39–0.82)	3.02, $P = 0.08$	1.94 (0.92–4.09)
ADL disability	16.91, $P < 0.001$	0.38 (0.24–0.60)	0.42, $P = 0.51$	1.36 (0.54–3.44)
Sum Trauma	0.54, $P = 0.46$	1.01 (0.98–1.05)	3.70, $P = 0.05$	1.06 (1.00–1.11)
PTSD symptom clusters				
Re-experiencing	3.32, $P = 0.07$	1.05 (1.00–1.10)	10.23, $P \leq 0.001$	1.11 (1.04–1.19)
Avoidance	4.19, $P = 0.04$	0.90 (0.82–0.99)	0.69, $P = 0.41$	0.95 (0.83–1.08)
Emotional numbing	21.72, $P < 0.001$	1.10 (1.06–1.15)	0.51, $P = 0.51$	1.02 (0.96–1.09)
Dysphoric arousal	1.60, $P = 0.21$	1.04 (0.98–1.10)	0.02, $P = 0.89$	0.99 (0.91–1.09)
Anxious arousal	13.63, $P < 0.001$	0.87 (0.80–0.94)	0.57, $P = 0.45$	0.96 (0.86–1.07)

Covariates for the quadratic logistic regression were identical to those of the linear logistic regression; covariate values were, therefore, identical for each equation and not reported twice.

small, especially when considered in relation to the collective effect size of the covariates. Specifically, ADL disability, number of lifetime traumas, gender, education, income, race, and ethnicity explained an estimated 30% of the variance in probable PTSD. While binary effects were significant, the U-shaped quadratic effect explained the most variance in probable PTSD diagnosis (2%). Regardless of how it was modeled, exercise frequency only explained a small amount of incremental variance in probable PTSD after adjusting for covariates. With this caveat in mind, these results nevertheless suggest that veterans who reported exercising 1–6 days per week had the lowest prevalence of probable PTSD, while those who did not exercise or who exercised every day had the highest prevalence of probable PTSD. Phrased alternatively, relative to veterans without probable PTSD, those with probable PTSD were nearly twice as likely to report no weekly exercise or daily exercise and were nearly half as likely to report exercising 1–6 days per week. These results are consistent with previous work suggesting that exercise may help protect against the development of psychiatric disorders, including PTSD (13), and that intermediate exercise frequency (i.e., 2–5 days/week) may convey the most benefit to mental health (30). However, the present results may also be interpreted to suggest that living with PTSD may drive some veterans to avoid exercise altogether or exercise every day or, conversely, may demotivate some veterans from engaging in some weekly physical exercise.

The current study is the first of which we are aware to utilize a nuanced, five-factor model of PTSD symptom clusters to examine how heterogeneous aspects of the PTSD phenotype relate to frequency of self-reported engagement in physical exercise, including the tendency to exercise excessively or not at all. Results revealed that PTSD symptom clusters were differentially associated with non-engagement in physical exercise or daily engagement in physical exercise (relative to intermediate exercise frequency [1–6 days/week]). Specifically, emotional numbing and anxious arousal symptoms were most strongly associated with no weekly exercise, while re-experiencing symptoms were most strongly associated with daily exercise. These PTSD symptom cluster findings may be reflective of PTSD symptoms differentially promoting experiential avoidance or anhedonia in ways that may influence exercise frequency. Specifically, highly avoidant veterans may exercise every day to avoid intrusive thoughts and emotional discomfort associated with re-experiencing symptoms (35, 36). Similarly, the positive association between anxious arousal and a lack of weekly exercise may be reflective of a tendency to experientially avoid (33) due to fear that exercise may trigger symptoms of hyperarousal (32, 33) or fear of the somatic sensations that result from exercise (44, 45) Conversely, anhedonic symptoms related to emotional numbing may deter some veterans from exercising at all due to insufficient motivation or a lack of experiential pleasure derived from exercising (34). Alternatively, some weekly—but not daily—

engagement in physical exercise may help mitigate symptoms of emotional numbing, which is consistent with the well-established finding of an anti-depressant effect of exercise (46).

Although there are several evidence-based approaches suggested for the treatment of PTSD, prior work suggests veterans diagnosed with PTSD often benefit less from psychotherapy than non-military populations. For example, half of veterans who received treatment for PTSD continued to meet criteria for this disorder at posttreatment (5, 47). This lack of responsiveness could be due to a variety of factors unique to veterans, such as trauma type and frequency of exposure to traumatic events (5, 48). When considered in light of data from clinical trials that demonstrate the efficacy of exercise as a treatment for depression (46), the present findings justify further exploration of the potential for exercise as a stand-alone treatment or adjunct to psychotherapy and medications (49). Such trials would also allow researchers to examine the causal effects of exercise on PTSD symptoms. Exercise may ultimately provide a cost-efficient and easily accessible technique for reducing PTSD risk or promoting recovery following trauma exposure (13, 50). Indeed, some emerging research suggests that exercise training is safe, acceptable, and helps reduce PTSD symptoms in older veterans with PTSD (5, 48).

Limitations of this study must be noted. First, given the cross-sectional design of the study, causal inferences regarding the relation between exercise and PTSD are speculative; exercise may help mitigate or prevent PTSD symptoms, but PTSD symptoms may just as well influence exercise behaviors. Future research should utilize mixed-method, longitudinal, and randomized controlled designs to better understand how engagement in physical exercise is temporally and causally linked to PTSD. Second, the present study used a single-item, self-report measure of exercise frequency, which has unknown reliability and validity; as such, results should be interpreted with caution. This single-item measure does not capture the diversity of exercise behaviors, which may be differentially associated with PTSD. Third, while we adjusted for ADL disability, it is possible that other illnesses or physical injuries that do not affect basic ADLs (e.g., asthma, chronic pain) may have limited engagement in physical exercise; further research is needed to evaluate this possibility. With these limitations in mind, future research on the relation between exercise and PTSD should include more comprehensive and objective assessments of exercise frequency, intensity, and type; and employ multi-modal experimental protocols that have a greater degree of control over the assessment of "dosing" of physical exercise. The latter is particularly important as some research suggests that exercise intensity may be a key factor that influences the associations between exercise behavior and PTSD symptoms (12, 26, 51).

Notwithstanding these limitations, results of this study suggest that frequency of physical exercise is associated with the prevalence of probable PTSD in U.S. military veterans. They further indicate the nature of this association is non-linear and U-shaped, with veterans who reported exercising 1–6 days per week having the lowest prevalence of probable PTSD and those who reported no weekly exercise and daily exercise having the highest prevalence of probable PTSD. Further research is needed to replicate these findings in more diverse samples of U.S. veterans; characterize temporal/causal effects of exercise on PTSD symptoms and vice versa with longitudinal designs or clinical trials; and to determine psychobiological mechanisms that mediate the relation between exercise and PTSD risk and resilience.

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Declarations of interest

None.

Date availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Peer Review

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Fig. S1. Distribution of PCL-S total and factor scores within the entire sample (n = 2764).