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Physical Fitness Influences Stress Reactions to Extreme Military Training

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ABSTRACT Background: Physical fitness and physical conditioning have long been valued by the military for their roles in enhancing mission-specific performance and reducing risk of injury in the warfighter. It is not known whether physical fitness plays a causal role in attenuating acute military stress reactions or the evolution of post-traumatic stress disorder. Objective: The objective of this study was to determine whether physical fitness influences the impact of stressful events during military survival training in 31 men. Methods: Participants self-reported their most recent Physical Readiness Test scores and completed a trait anxiety measure before survival training. Participants also completed the Impact of Events Scale (IES) 24 hours after training. Results: Aerobic fitness was inversely associated with the total IES score ($p < 0.01$, adjusted $R^2 = 0.19$). When adjusted for trait anxiety, this relationship was substantially attenuated and no longer significant ($p = 0.11$). Trait anxiety was inversely associated with aerobic fitness ($p < 0.05$) and positively related to IES ($p < 0.001$). Conclusions: Physical fitness may buffer stress symptoms secondary to extreme military stress and its effects may be mediated via fitness-related attenuations in trait anxiety.

INTRODUCTION

Post-traumatic stress disorder (PTSD) is an important public health and military problem, since PTSD symptoms are thought to occur in as many as 15 to 20% of individuals exposed to combat.¹ However, the temporal course of PTSD development is difficult to quantify in an experimental setting. One important early marker of PTSD evolution in individuals exposed to extreme conditions concerns the impact of stressful events, including avoidance (avoiding situations that remind one of a previously experienced traumatic event), intrusion (experiencing intrusive or disturbing thoughts as a result of the event), and heightened arousal (experiencing anger, irritability, heightened startle response, and hypervigilance as a result of the event).^{2,3}

There is a sustained interest in understanding characteristics that may serve as buffers against (or vulnerabilities for) acute stress reactions and subsequent PTSD development.⁴⁻⁶ One such factor has been termed resilience^{6,7} or psychological hardiness.⁵ These constructs are generally understood as an

ability to “bounce back” from stressful or traumatic events. Research has shown that psychological hardiness buffers the effects of work-related stress in health care workers,⁸ athletes,⁹ casualty assistance workers,¹⁰ and Persian Gulf War soldiers.⁵ Other factors that may influence stress reactions and PTSD development include depression, anxiety,^{11,12} social support,¹³ and intelligence.¹² Furthermore, proposed neurochemical, neuropeptide, and hormonal predictors include neuropeptide Y,¹⁴ cortisol, dehydroepiandrosterone,¹⁵ dopamine, and benzodiazepine receptors.⁶ Finally, several neural mechanisms of reward and motivation (e.g., hedonia, optimism) and adaptive social behavior (e.g., altruism, teamwork) have also been suggested to serve protective roles.⁶

Physical fitness and physical conditioning have long been valued by the military for their roles in enhancing mission-specific performance and reducing risk of injury in the warfighter. It is not known whether physical fitness plays a causal role in attenuating acute military stress reactions or the evolution of PTSD. However, there is substantial literature documenting possible buffering effects of physical activity, exercise, and/or physical fitness with respect to stress reactivity,^{16,17} state and trait anxiety,^{18,19} and depression,^{20,21} as well as positive links to neurogenesis²²⁻²⁴ and cognitive function across a wide variety of populations.²⁴ In light of this literature, it is plausible that physical fitness may influence stress reactions to intense military training.

The purpose of this study was to examine whether physical fitness influences the impact of stressful events during military survival training. We hypothesized that physical fitness would buffer these stress reactions, and that this observed effect would be mediated through attenuations in trait anxiety.

METHODS

The present study was part of a larger ongoing program of research examining individual differences in human perfor-

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mance and stress resilience in extreme military environments. The study was approved by the Institutional Review Board at the Naval Health Research Center (San Diego, California). Before participation, all prospective participants were informed of their rights as human subjects and each gave written, informed consent to participate.

Thirty-one male participants completed measures of physical fitness and trait anxiety ~3 weeks before participating in Survival, Evasion, Resistance, and Escape (SERE) training in the San Diego area. SERE training and our associated program of research have been described in detail elsewhere.²⁵ Briefly, U.S. military members at high risk of capture are required to attend SERE training, which includes a period of confinement in a Resistance Training Laboratory (RTL). After an initial phase of classroom-based didactic training, students are taken to the field where they receive applied training in survival, evasion, resistance, and escape techniques. Students are then released into the field and tasked with the goal of evading enemy captors. Upon eventual capture, students are taken to the RTL where they are expected to apply their recently learned skills of resistance to political indoctrination and captivity-related challenges. The structured, choreographed nature of this training platform provides a unique and unprecedented medium in which to examine human stress and performance in a realistic military context. Moreover, since a component of SERE training is designed to simulate the prisoner-of-war experience, it offers a unique medium in which to study the effects of mock captivity stress on many aspects of human functioning. Twenty-four hours after the conclusion of SERE training (i.e., release from RTL), participants completed the Impact of Events Scale-Revised (IES-R).³

Physical Fitness

Prior to SERE training, participants reported the results of their most recent Physical Readiness Test (PRT). Military personnel are required to maintain a standard level of physical fitness by scoring satisfactorily on the PRT, which is administered semiannually. The time required to complete a 1.5-mile run on a standardized course as part of the PRT was used as a measure of aerobic fitness (lower values indicate higher fitness). The maximum numbers of sit-ups and push-ups performed in 2 minutes were used as measures of core fitness and upper body fitness, respectively. Self-reported physical fitness test scores have been shown to correlate highly with objectively recorded scores. Specifically, Jones et al.²⁶ found self-reported push-ups, sit-ups, and run time during an Army physical fitness test to be correlated to objectively recorded scores at 0.83, 0.71, and 0.85, respectively.

Trait Anxiety

Prior to SERE training, self-report of anxiety was assessed with the trait portion of the Spielberger State-Trait Anxiety Inventory. The 20-item trait anxiety inventory asks respondents to describe how they generally feel, using a 4-point Likert-type scale (almost never, sometimes, often, almost always). Examples of

items include "I feel pleasant," "I worry too much about something that does not matter," and "I make decisions easily." The trait anxiety inventory is scored by reverse coding each positive item and then summing across all items. Scores range from 20 to 80, with lower scores indicating less anxiety and higher scores indicating a greater level of anxiety. The scale is widely used, and its reliability and validity has been established in several different populations.^{27,28} Internal reliability of the trait anxiety scale in the current study was acceptable (Cronbach's $\alpha = 0.77$).

Impact of Events Scale-Revised

The IES-R was administered 24 hours after the conclusion of SERE training. This self-report measure is designed to assess current subjective distress for any specific life event. The IES-R has 22 items, comprising three subscales corresponding to the Diagnostic and Statistical Manual of Mental Disorders—Fourth Edition²⁹-specified PTSD symptoms: avoidance (IES-avoidance; mean of eight items measuring the extent to which the respondent avoids situations that remind him or her of the stressful or traumatic event), intrusion (IES-intrusion; mean of eight items assessing the extent to which one experiences intrusive thoughts), and hyperarousal (IES-arousal; mean of six items measuring anger, irritability, heightened startle response, and hypervigilance). A total IES score (IES-total) is composed of the sum of the three subscales. With this scale, respondents are shown a list of difficulties people sometimes have after stressful life events and are asked to indicate how distressing each difficulty has been with respect to a stressful captivity-related problem on a scale of 0 (not at all) to 4 (extremely). Adequate reliability and predictive validity have been shown for this scale^{30,31} and Cronbach α reliabilities in the present sample were 0.73, 0.79, and 0.70 for IES-arousal, IES-avoidance, and IES-intrusion, respectively. Cronbach α reliability for IES-total was 0.89.

Data Analysis

Preliminary analysis incorporated the use of normal probability and residual plots to assess compliance with the assumption of linear regression and screen for the presence of influential outlying data values. These plots revealed that the normal distribution was an appropriate assumption. Means (and SDs) and percentages were used to describe continuous and discrete characteristics, respectively. Linear regression was used to examine predictors of stressful events during SERE training. Pearson correlation coefficients compared the relative strength of these associations.

To assess confounding and the mediating influence of trait anxiety on the relation of aerobic fitness with the impact of stressful events during SERE training, we examined the change in the β coefficient for run time (aerobic fitness) when each factor was added individually to a base model including only run time. SPSS Statistical Software System, version 15 (SPSS Inc., Chicago, Illinois) was used to perform all analyses. All tests of hypotheses were two-sided and based on a type I error rate of 0.05.

TABLE I. Characteristics of Military Men Ages 19 to 30 Years ($N = 31$)

Characteristic	Mean (SD)
Age (years)	21.7 (2.2)
Height (cm)	179.6 (7.1)
Weight (kg)	78.2 (7.3)
Body mass index (kg/m^2)	24.2 (1.6)
Years of military service	1.8 (0.9)
Push-ups ^a (repetitions)	88.8 (13.2)
Sit-ups ^a (repetitions)	99.1 (12.9)
Run time ^a (min)	9.6 (0.8)
IES-arousal	0.9 (0.7)
IES-avoidance	0.8 (0.6)
IES-intrusion	1.1 (0.5)
IES-total	2.8 (1.6)
Trait anxiety	30.2 (5.2)
Education, (%)	
High school graduate	77.4
College graduate	22.6
Military occupational specialty, (%)	
Special warfare (SEAL) student	19.4
Aviation warfare student	80.6

^a Maximum number of push-ups and sit-ups completed during 2-minute sessions; number of minutes to run 1.5 miles.

RESULTS

Characteristics of the Sample

Detailed sample characteristics are presented in Table I. Mean age, body mass index (BMI), and years of military service for this sample were 21.7 years ($SD = 2.2$), 24.2 kg/m^2 ($SD = 1.6$), and 1.8 years ($SD = 0.9$), respectively. Highest level of education reached was high school for most subjects (77.4%) and 22.6% were college educated. Most subjects were Caucasian (87.1%). Regarding military occupational specialty, 80.6% were students under instruction to become aviation warfare specialists/rescue swimmers, while the remaining 19.4% were students undergoing advanced instruction to become special warfare (SEAL) officers. Mean trait anxiety scores in the present sample were slightly lower than those found in a normative college-aged population.²⁷

Predictors of Stressful Events during Survival Training

Univariate predictors of the impact of stressful events are indicated in Table II. Age and BMI were not associated with IES-total. Years of military service demonstrated a nonsignificant inverse relationship with IES-total ($p = 0.08$), although years of military service was fairly restricted in range (mean = 1.80, $SD = 0.87$, range = 4). Trait anxiety was positively associated with IES-total ($p = 0.001$). SEAL students demonstrated a notably lower IES-total than aviation warfare students (1.90 [$SD = 1.70$] versus 3.00 [$SD = 1.53$]) although these differences did not reach statistical significance ($p = 0.18$). Similarly, there was a trend for differences between participants with a high school (mean = 3.05, $SD = 1.53$) versus a college education (mean = 1.82, $SD = 1.53$) ($p = 0.07$).

TABLE II. Univariate Predictors of the Impact of Stressful Events during Military Survival Training in Men Ages 19 to 30 Years ($N = 31$)

Variables	Impact of Stressful Events—Total			
	β	SE	r	p
Age (years)	-0.042	0.132	-0.06	0.8
Body mass index (kg/m^2)	0.077	0.179	0.08	0.7
Years of military service	-0.587	0.318	-0.32	0.08
Trait anxiety	0.173	0.047	0.56	0.001

Relationships between Physical Fitness and Impact of Stressful Events

Univariate relationships of measures of physical fitness with the impact of stressful events during survival training are shown in Table III. As indicated, upper body fitness as measured by number of push-ups performed in 2 minutes was inversely associated with IES-avoidance ($p = 0.02$) and IES-total ($p = 0.05$). Core fitness as indicated by number of sit-ups performed in 2 minutes was inversely associated with IES-arousal ($p = 0.04$) as well as IES-total ($p = 0.04$). Aerobic fitness as indicated by number of minutes to run 1.5 miles (higher times indicating lower fitness) was inversely associated with IES-arousal ($p = 0.007$), IES-avoidance ($p = 0.02$), IES-intrusion ($p = 0.05$), and IES-total ($p = 0.008$).

Assessment of Mediating Role of Anxiety

Due to its robust relationship to impact of stressful events as well as substantial relationships with core ($p = 0.07$) and upper body fitness ($p = 0.001$), aerobic fitness was selected as the physical fitness variable with which to investigate possible confounding as well as the mediating influence of trait anxiety. An examination of models assessing these relationships is demonstrated in Table IV. Whereas aerobic fitness was significantly associated with IES-total in the regression model ($p = 0.008$), this relationship was not appreciably altered when adjusted for age, BMI, years of military service, education, or military occupational specialty. When adjusted for trait anxiety, however, this relationship was substantially attenuated and no longer significant ($\beta = 0.544$, $p = 0.10$).

DISCUSSION

The present study was initiated to determine whether physical fitness influences the impact of events occurring during a stressful mock captivity phase of military survival training. We demonstrated that aerobic fitness was inversely associated with the impact of stressful events, and that this relationship may be mediated via fitness-related attenuations in trait anxiety.

To the best of our knowledge, this is the first study to link measures of physical fitness to acute military stress reactions, although the military has long valued physical fitness as a means of enhancing hardiness in the warfighter. Previous research has demonstrated convincing links between physical fitness and aspects of mental health in both clinical and healthy populations. As noted earlier, there is substantial literature documenting ben-

TABLE III. Univariate Relation of Physical Fitness Measures to the Impact of Stressful Events during Military Survival Training in Men Ages 19 to 30 years ($N = 31$)

Variables ^a	Impact of Stressful Events															
	Arousal				Avoidance				Intrusion				Total			
	β	SE	r	p	β	SE	r	p	β	SE	r	p	β	SE	r	p
Push-ups (repetitions)	-0.120	0.009	-0.24	0.2	-0.017	0.007	-0.41	0.02	-0.013	0.007	-0.33	0.1	-0.043	0.021	-0.36	0.05
Sit-ups (repetitions)	-0.020	0.009	-0.38	0.04	-0.013	0.008	-0.30	0.1	-0.013	0.007	-0.30	0.1	-0.046	0.021	-0.37	0.04
Run time (minutes)	0.392	0.137	0.47	0.007	0.286	0.117	0.41	0.02	0.240	0.117	0.36	0.05	0.922	0.323	0.47	0.008

^a See Table I footnote and "Methods" for a description of these variables.

TABLE IV. Various Models Assessing the Relation between Aerobic Fitness and the Impact of Stressful Events during Military Survival Training ($N = 31$)

Models ^a	Impact of Stressful Events—Total		
	β	SE	p
Run time (minutes)	0.922	0.323	0.008
Run time (minutes) + age	0.918	0.330	0.009
Run time (minutes) + body mass index	0.957	0.327	0.007
Run time (minutes) + years of military service	0.961	0.302	0.004
Run time (minutes) + education	0.881	0.440	0.05
Run time (minutes) + military occupational specialty	0.955	0.422	0.03
Run time (minutes) + trait anxiety	0.544	0.326	0.1

^a See Table I footnote and "Methods" for a description of these variables.

eficial effects of physical activity, exercise, and/or fitness relative to stress reactivity,^{16,17} anxiety,^{18,19} depression,^{20,21} as well as neurogenesis,²²⁻²⁴ and cognitive function.²⁴ Georgiades et al.,¹⁷ for example, studied the effects of exercise and weight loss on mental stress-induced cardiovascular responses in individuals with high blood pressure. After 6 months, participants in an exercise group and participants in a behavioral weight loss group (including exercise) had lower levels of systolic blood pressure, diastolic blood pressure, total peripheral resistance, and heart rate both at rest and during mental stress, compared with inactive controls.

In another randomized trial, Blumenthal et al.²⁰ showed that 16 weeks of exercise treatment was as effective as antidepressant medication in reducing depression among patients with major depressive disorder. In a recent animal study, Pereira et al.²² showed that exercise had a direct impact on dentate gyrus cerebral blood volume, a hippocampal sub-region known to support neurogenesis, in mice. These researchers then showed similar effects in humans and that these changes were correlated to cardiopulmonary and cognition function. Given the relationship of the hippocampus to memory and stress,^{32,33} this offers mechanistic insight into the possible link between exercise training, concomitant improvements in physical fitness, and stress resilience.

As an extension of these and related findings, Tsatsoulis et al.³⁴ proposed that, since the stress response is a neuroendocrine mechanism that occurs in anticipation of physical action, physical activity should be the natural means to prevent the conse-

quences of stress (i.e., strain). These authors offer additional mechanistic possibilities, including peripheral actions influencing metabolism such as insulin sensitivity and the partitioning of fuels toward oxidation rather than storage. The extent to which these metabolic processes are causally implicated in stress resilience awaits further research.

Limitations of this study should be addressed. We used a less-than-optimal measure of physical fitness—self-reported scores from a recent PRT. This, of course, is less desirable than "gold standard" measures such as peak volume of oxygen uptake (VO_2) using metabolic technology. However, the fact that we observed robust relationships between aerobic fitness and military stress reactions despite its crude measurement justifies additional research with more sophisticated tools. There are two important strengths of the current study. First, our findings regarding the link between physical fitness and military stress reactions is novel and may open the door to a new line of inquiry that may improve our understanding of prevention and treatment for combat stress and PTSD. Second, this study was conducted within the survival training environment, offering an unprecedented level of ecological validity. Specifically, SERE training is a standardized and systematic, yet realistic and intense, course of training modeled after the experiences of American prisoners of war from the Korean and Vietnam conflicts. Short of actual military combat, it is among the best forums in which to examine human reactions to acute military stress in a controlled fashion.

More research is needed to better understand the possible relationships between physical fitness and acute military stress reactions, including both resilience and vulnerability factors. Wherever possible, future research should employ more sophisticated measures of aerobic (e.g., peak VO_2 uptake) and muscular fitness (e.g., percentage of 1 repetition maximum or 10 repetition maximum). More research is also needed to test our proposed mediating role of trait anxiety in the physical fitness-stress reaction relationship as well as other possible mediating factors. Furthermore, it would be of interest to examine the relationship of physical fitness to other military stress endpoints, such as hormonal markers (e.g., cortisol), dissociative symptoms (i.e., how perceptually connected or disconnected an individual is relative to his or her environment), as well as cognitive function and overt performance. Also, it would be particularly valuable to prospectively examine the effects of exercise training and concomitant fitness changes on military stress reactions in a randomized, controlled setting.

In summary, we examined the influence of physical fitness on the impact of events occurring during a stressful mock captivity phase of military survival training. We demonstrated that aerobic fitness was inversely associated with the impact of stressful events, and that this relationship may be mediated via fitness-related attenuations in trait anxiety.

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14. ABSTRACT (maximum 200 words)

OBJECTIVE. Although several risk factors for posttraumatic stress disorder (PTSD) have been identified, researchers continue to search for novel predictors of this disorder. In the current study, we prospectively examined whether physical fitness influences the impact of stressful events (a known predictor of PTSD) during military survival training in 31 men. We hypothesized that physical fitness would buffer stress symptoms and that the effect would be mediated via a fitness-associated attenuation in trait anxiety. **METHODS.** Participants self-reported their most recent Physical Readiness Test scores and completed a trait anxiety measure prior to survival training. Participants also completed the Impact of Events Scale (IES) 24 hours posttraining. **RESULTS.** Aerobic fitness was inversely associated with a total IES score ($\beta = .015$, $p < .01$, adjusted $R^2 = .19$), independent of age, body mass index, years of military service, education, and Military Occupational Specialty. When adjusted for trait anxiety, this relationship was substantially attenuated and no longer significant ($\beta = .009$, $p = .11$). Trait anxiety was inversely associated with aerobic fitness ($r = -.43$, $p < .05$) and positively related to IES ($r = .56$, $p < .001$). **DISCUSSION.** These results suggest that physical fitness may buffer stress symptoms secondary to extreme military stress, and its effects may be mediated via fitness-related attenuations in trait anxiety.

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