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Stress Reactivity in Fire Fighters: An Exercise Intervention

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This experiment was designed to investigate the efficacy of 16 weeks of exercise training as an intervention to reduce the psychophysiological response of fire fighters to psychological stress. Fifty-three members of the Austin Fire Department (AFD) were recruited as participants and were randomly assigned to either exercise on a rowing ergometer or to continue their present modes of exercise training. Psychological stress was induced by a computerized version of the AFD Strategy and Tactics Drill (STD), in which participants responded to a simulated fire scene. Participants completed the STD prior to and following the exercise intervention. Prior to training, the groups did not differ in their cardiovascular response to the STD. Significant group differences were observed after training, in which exercise-trained participants reacted with significantly lower pulse and mean arterial pressure than their counterparts in the control condition. Exercise participants also reported significantly less stress-related state anxiety and negative affect. Exercise training appears to be a useful intervention to reduce the response to fire-related psychological stress in fire fighters.

KEY WORDS: fire fighters; exercise; stress reactivity; mean arterial pressure; anxiety.

Firefighting is a hazardous and physically demanding occupation. Whether carrying a 200-lb victim to safety or manning a hose wearing 50 lbs. of protective gear, fire fighters routinely perform physically demanding tasks in the presence of extreme personal danger. Given the inherent danger of fire fighting,

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psychological stress is an ever present component of the profession (Murphy, Beaton, Pike, & Johnson, 1999; Beaton, Murphy, Johnson, Pike, & Corneil, 1998). As a result, any intervention that lessens the experience of psychological stress would be a useful part of a fire fighter's routine. Exercise training might provide such a benefit.

The physical benefits of exercise for fire fighters are obvious. In fact, physical fitness is an important component in the screening of fire fighter candidates (Davis, Dotson, & Santa Maria, 1982), and ongoing physical training is recommended to maintain the performance standards of fire fighters (Brownlie et al., 1985; Ellam, Fieldman, Garlick, Goldsmith, & Pateman, 1994). Exercise training has also been associated with mental health benefits. For example, exercise has been shown to reduce both depression (North, McCullagh, & Tran, 1989) and anxiety (Landers & Petruzzello, 1994). Of particular interest to fire fighters, however, may be the potential of exercise to lesson reactivity to psychological stress.

A meta-analytic review by Crews and Landers (1987) examined the results of 34 studies having 92 effect size estimates from 1,449 participants. Results indicated that aerobic fitness was negatively correlated with the response to psychological stress. That is, high-fit participants, on average, experience a lowered response to stress and recovered faster than their low-fit counterparts. However, exercise training has generally resulted in a change in the absolute response to stress, that is, group differences in blood pressure during stress, with no relative change in reactivity, and no difference in the percentage increases in blood pressure from baseline. Thus, the buffering effects for fitness are removed when controlling for baseline values. This pattern of results can occur because exercise reduces the resting values of most stress indicators, such as blood pressure and pulse (McArdle, Katch, & Katch, 1991). As a result, although high-fit individuals may experience lower absolute blood pressure due to training-induced low baselines, they may respond with an equal or greater relative change in blood pressure during stress (Claytor, 1991; Holmes, 1993). This pattern of results has recently been demonstrated in both children (Franks & Boutcher, 1999) and postmenopausal women (Boutcher, Craig, & Nurhayati, 1999) in their cardiovascular response to the Stroop task (Frankenhaeuser & Johansson, 1976). In both studies, exercise trained participants experienced significantly lower blood pressure during stress. However, no differences remained when baseline values were controlled. Thus, it appears that increasing the fitness of fire fighters would likely result in less absolute cardiovascular reactivity with little effect on relative reactivity to stress.

The failure of exercise to lessen relative reactivity does not imply that exercise is not a useful intervention to buffer the experience of stress. Less absolute stress and a quicker recovery from stress would likely improve the overall experience of stress (Crews & Landers, 1987). However, even these benefits must be questioned prior to applying them to fire fighters. First, most experiments are cross-sectional and have compared people at the extremes of fitness. It has already been noted that exercise is an important part of fire fighting training. If a fire fighter's present level of exercise is sufficient to maintain high fitness, then an exercise intervention would not be expected to provide an added benefit. A second question regards the ability to generalize earlier findings to fire-related stress. The majority of experiments have exposed participants to purely cognitive challenges to induce stress, for example, the Stroop task, mental arithmetic, or public speaking. Clearly, these stressors have little to do with the demands of fire fighting. Therefore, a task that more closely resembles fire fighting must be investigated before recommending the use of exercise to buffer the experience of stress in fire fighters. What is clearly needed is an experiment that randomly assigns fire fighters to an exercise intervention and assesses the impact of exercise training on fire-related stress. The present experiment was designed to fill this void. It was predicted that although there would be no differences in the cardiovascular and psychological responses to stress at baseline, groups would differ after training. Specifically, in comparison to those participants in the control condition, trained fire fighters were predicted to exhibit lower absolute levels of mean arterial pressure (MAP) and heart rate (HR) during stress, as well as lowered anxiety and negative affect in anticipation of stress. It was not clear if exercise training would result in relative differences between groups.

METHOD

Participants

One hundred-eleven fire fighters were approached to participate through on-site recruitment presentations at six fire stations. Of those, 53 (48%) agreed to participate. The participants were healthy, currently active male and female fire fighters (50 males, 3 females, age 35.7 ± 7.3 years) employed by the Austin (Texas) Fire Department (AFD). No bias was made toward race, education level, or socioeconomic status, and participation reflected the diversity represented in the Austin Fire Department. No remuneration was provided for participation in this study.

Procedure

Description of Independent Variable

Description of the Exercise Mode Selected. Rowing was selected as the exercise intervention because it allows for full body training and can be structured to enhance both aerobic fitness and anaerobic power. In addition, performance on a 2 min maximal effort rowing test is closely related to performance on the Combat Challenge (Stevenson & Farrar, 1996), a test used to simulate fire fighting activity. Two rowing ergometers were placed at each of the three fire stations that served as training sites. This was done so as to limit access to the rowing ergometers to exercise participants. As a result, participants were randomly assigned to training or control conditions as a function of their fire station. The Control group continued with a normal life style, which may have included personal exercise programs, as long as the rowing ergometer was not utilized. The Training group was also allowed to include any additional activity of their choosing provided that the rowing exercise bouts were performed as required.

Familiarization Period. Prior to any testing, all participants underwent 4 weeks of familiarization with the Concept II Rowing Ergometer. During this period, each participant received at least four sessions of personal instruction by a former elite rower who had 10 years of competitive rowing experience. Participants were also required to row, on their own, throughout the 4 weeks. The familiarization period was designed to ensure proper technique and adequate stabilization of the rowing stroke so as to minimize injury and provide valid performance assessments. Baseline physiological and psychological testing was conducted following the 4 week familiarization period, with posttesting conducted following 16 weeks of training.

Physical Training. Following the baseline testing, participants in the training condition commenced with 16 weeks of rowing exercise composed of four, 40 min exercise bouts each week. The intervention began with low-to-moderate intensity rowing, focusing on consistency in technique and establishing an aerobic base. The training program then gradually introduced shorter duration, higher intensity anaerobic bouts combined with the low-to-moderate intensity rowing. The training program ended with a proper taper period for all exercising participants and two weeks of re-familiarization to rowing for the control group.

Participants in the training group were provided training logs to record their progress. These logs were checked weekly by a researcher to ensure adherence and to respond to any questions or concerns that participants may have had regarding their training and health status. In addition, each training group participant was videotaped while rowing and the tape reviewed in the presence of both the researcher and participant to ensure that proper rowing technique was maintained.

Description of Data Collection

Physical Testing. Physical testing was conducted following the 4 week familiarization phase (baseline) and following 16 weeks of training (posttest). To determine the impact of the training on fitness, participants completed 2 physical tests: (1) a graded exercise test to determine aerobic fitness via maximal oxygen uptake ($\dot{V}O_2$), and (2) a 2 min maximal effort test of anaerobic power. To assess maximum $\dot{V}O_2$, rowing intensity was progressively increased in 2 min stages for the first 9 min, with intensity increased every 1 min afterward. This design will generally elicit fatigue within 10–12 min. Participants' expired gases were measured via a Sensormedics 2900 metabolic cart. Maximal $\dot{V}O_2$ was determined as the value at which a plateau was reached in oxygen uptake despite continued increases in exercise intensity. The power test consisted of a 2 min maximal effort exercise bout on the rowing ergometer, with power determined as the average watts generated during the 2 min test. Both tests utilized the Concept II Rowing Ergometer that was used for training, and participants were allowed 15 min to warm up.

Psychological Stress. As with the physical testing, the reaction to stress was examined following the 4 week familiarization phase (baseline) and following 16 weeks of training (posttest). To induce psychological stress, participants completed a video-based Strategy and Tactics Drill (STD), in which they were asked to make decisions based on an emergent fire scene as viewed on a television screen. Participants performed this task in the presence of an official from the Austin Fire Department who oversaw the test and prompted the participant for answers. This official was kept blind to the experimental condition. The participants were told that their performance was being evaluated by the official and were asked to behave as if they were the incident commander, charged with directing personnel in fighting the fire. The STD began with a scene depicting a two-story building with smoke coming from the second floor. Participants were informed that there "may be a child in the house." Throughout the test, the fire official increased the magnitude of the fire and prompted the participant for decisions. All responses were given orally.

Description of Stress Measures. Heart rate and blood pressure were recorded by a 3-lead ECG monitor and automatic blood pressure cuff (Colin model #STBP-680). These cardiovascular measures were assessed: (1) pre-stress; (2) prior to the STD; (3) at 1 and 2 min into the STD; and (4) immediately following the STD. Pre-stress measures were assessed following a 10 min period of quiet rest, prior to any instructions for the STD. A second measure was completed following instructions, but prior to beginning the STD. Questionnaires were completed at two time points: (1) following instructions but prior to the STD, and (2) following completion of the STD. Questionnaires included the Positive Affect-Negative Affect Schedule (PANAS: Watson, Clark, & Tellegen, 1988) and the short form of the State Anxiety Inventory (SAI: Speilberger, Gorsuch, & Lushene, 1970). The PANAS is a 20-item questionnaire that is scored on a 5-point Likert-type scale anchored with 1 "very slightly or not at all" and 5 "extremely." Over 10 years of testing, the negative and positive affect scales are generally uncorrelated with one another and have adequate reliability, with alpha coefficients consistently above the .70 criterion (Watson et al., 1988;

Watson, Wiese, Vaidya, & Tellegen, 1999). The SAI is an 8-item questionnaire that is scored on a 4-point Likert-type scale anchored with 1 "not at all" and 4 "very much so." The SAI has been supported repeatedly as a reliable and valid indicator of state anxiety, with the 8-item version being preferred to the long version when being administered multiple times (Speilberger, 1979). Procedures for the posttest were identical to the pretest, with the only exception being the use of a separate fire scene for the STD. Results for each of these tests were made available upon completion of the study.

Statistical Analysis

Given the mixed, factorial design, a 2 (Group) × 2 (Time) ANOVA with repeated measures on the last factor was used to determine changes in physical fitness following exercise training. Relative reactivity was determined by controlling for pre-stress values of MAP and HR prior to receiving instructions for the STD. To accomplish this, a 2 (Group) × 2 (Time) ANCOVA with repeated measures on the second factor was used, with pre-stress scores selected as the covariate. Because of the predicted effects of exercise training, a significant Group × Time interaction was predicted for these variables. Significant interactions were followed by a test of the simple effects of Time within each level of Group. Post hoc comparisons were made with a modified Bonferroni correction (Keppel, 1991). Lastly, effect sizes (ES) were calculated as the difference between pretest and posttest scores, divided by the pooled standard deviation (Thomas & French, 1986).

RESULTS

Of the initial 53 participants, 41 completed all phases of the study (38 males, 3 females); 21 were in the training condition and 20 in the control condition. Descriptive data are presented in Table 1. Training participants weighed approximately 6.7 kg more than Control participants, with a higher percent of body fat accounting for this difference. The participants did not differ on level of experience ($M = 12.37 \pm 4.23$ for controls; and $M = 10.92 \pm 5.49$ for trained participants) or any other descriptive data.

Physical Fitness

Maximal $\dot{V}O_2$ and a 2 min power test were used to determine whether rowing produced a significant change in fitness. These data are presented in Table 1. Given the differences in fat mass between the groups, maximal power

Table 1. Descriptive Data for Fire Fighters in the Control and Exercise Training Conditions: Means (Standard Deviations)

Variable		Control	Training
Age	Pre	35.59 (7.41)	34.52 (7.13)
Height	Pre	177.19 (6.88)	179.16 (8.01)
Body weight (kg)	Pre	80.72 (9.72)	87.89** (11.10)
	Post	82.24 (10.32)	89.04** (11.47)
Lean body mass (kg)	Pre	66.80 (7.46)	68.17 (7.14)
	Post	67.64 (8.02)	69.22 (7.38)
Two min max rowing (average watts)	Pre	321.56 (61.91)	307.50 (62.93)
	Post	324.78 (70.03)	327.72* (55.80)
$\dot{V}O_2$max (ml O_2/kg LBM/min)	Pre	58.61 (5.20)	53.71 (5.57)
	Post	57.98 (4.73)	55.90* (4.80)

*Significant pre-post difference ($p < .05$). **Significant group difference ($p < .05$).

and $\dot{V}O_2$ were calculated per kg of lean body mass. This analysis revealed a significant group by time interaction, $F(1,39) = 7.94$, $p < .05$. Simple effects within groups revealed a significant increase over time for the training group, $F(1,39) = 9.82$, $p < .05$, with no change in maximal $\dot{V}O_2$ for the control group. Examination of the average watts produced over the 2 minute maximal rowing bout revealed similar results. There was a nearly significant group by pre-post interaction, $F(1,39) = 3.75$, $p = .06$. Given the a priori predictions of an interaction, and similar results for maximal $\dot{V}O_2$, this level of significance was considered sufficient to examine the simple effects within each level of group. These analyses revealed a significant increase in power over time for the training group, $F(1,39) = 6.02$, $p < .05$, with no change for the control group. Thus, the rowing intervention appears to have produced a significant increase in physical fitness.

Stress Reactivity

Cardiovascular arousal during stress was calculated by averaging the mean arterial pressure (MAP) and heart rate (HR) values that were obtained at 1 and 2 min into the Strategy and Tactics Drill (STD). These data are presented in

Table 2. This analysis revealed a significant group by pre-post interaction for MAP, $F(1,38) = 5.46$, $p < .05$. The simple effects within each level of Group indicated a significant reduction in MAP over time for the training group, $F(1,38) = 7.61$, $p < .05$, $ES = -.39$, with no change for the control group. Analysis of the HR data revealed a nearly significant group by pre-post interaction, $F(1,38) = 3.23$, $p = .07$. Given the a priori predictions of an interaction, and similar results for MAP, this level of significance was considered sufficient to examine the simple effects within each level of group. Over time, the training group showed a large reduction in heart rate stress reactivity, $F(1,38) = 22.51$, $p < .05$, $ES = -.43$, while the control group showed a smaller effect in the same direction, $F(1,38) = 5.07$, $p < .05$, $ES = -.16$.

A 2 (Group) × 2 (Pre-post) ANOVA with repeated measures on the second factor was used to analyze the questionnaire data, which are presented in Table 3. This analysis revealed a significant group by pre-post interaction for negative affect, $F(1,39) = 4.66$, $p < .05$. Simple effects within group revealed a significant reduction in negative affect for the Training group, $F(1,39) = 14.26$, $p < .05$, with no change for the control group. Similar analysis revealed a significant group by pre-post interaction for state anxiety, $F(1,39) = 6.72$, $p < .05$. Simple effects within group revealed a significant reduction in state anxiety over time for the training group, $F(1,39) = 23.71$, $p < .05$, with no changes for the control group.

Table 2. Pre- and Post-Training Stress Measures for Fire Fighters in the Control and Exercise Training Conditions[a]

	Control		Training	
	pre	post	pre	post
MAP				
rest	97.36	97.26	94.84	96.57
sd	8.01	9.69	7.01	6.60
stress	116.81	117.51	115.17	112.70
sd	9.47	11.16	8.17	8.05
Δ	19.45	20.25	20.33	16.13
adj	115.60	116.95	116.38	113.26*
HR				
rest	67.45	66.30	66.29	70.95
sd	7.74	10.63	10.36	11.38
stress	88.15	83.98	82.41	79.95
sd	17.95	15.63	12.06	12.11
Δ	20.71	17.68	16.12	9.00
adj	87.44	85.96*	83.11	77.97*

[a]Data presented are mean arterial pressure (MAP) and pulse (HR) at rest and during a stressful task. Adjusted scores have been controlled for pre-stress values.
*Significant pre-post difference ($p < .05$).

Table 3. Pre- and Post-Training Stress Measures for Fire Fighters in the Control and Exercise Training Conditions[a]

	Control		Training	
	pre	post	pre	post
State Anxiety				
mean	13.05	12.45	13.91	11.90*
sd	(2.33)	(2.54)	(3.65)	(2.09)
Positive Affect				
mean	32.90	33.25	31.62	32.71
sd	(4.56)	(5.26)	(6.58)	(5.70)
Negative Affect				
mean	13.40	12.95	14.48	12.95*
sd	(2.14)	(3.07)	(3.83)	(3.07)

[a]Data presented are measures of stress-related psychological state.
*Significant pre-post difference ($p < .05$).

DISCUSSION

This experiment was designed to examine the effects of 16 weeks of rowing exercise on the physical fitness and cardiovascular stress reactivity of fire fighters. Results indicated that rowing produced a significant change in fitness. In comparison to those who continued a normal training regimen, participants in the rowing condition responded with enhanced aerobic fitness and power. Aerobic fitness and power, as assessed with a rowing ergometer, have been shown to correlate with performance on the Combat Challenge (Stevenson & Farrar, 1996). Because the Combat Challenge is designed to emulate the demands of fire fighting, rowing appears to be a useful mode of physical training for fire fighters—even for those who are presently engaged in some sort of physical training. Results also support the stress buffering effects of rowing. Although there were no group differences prior to training, groups did differ in their cardiovascular reactivity to fire-related psychological stress after 16 weeks of rowing. This effect was clearly demonstrated with mean arterial pressure (MAP). After controlling for baseline values, rowers experienced significantly lower MAP during stress than did control participants. The effect was present but less clear with heart rate (HR). Although both groups responded with a reduction in HR during stress, the rowing participants experienced a greater relative reduction in HR. In addition, rowers reported less stress-related anxiety and negative affect prior to the posttest stress. Thus, not only did rowing provide increases in physical fitness, it also served to lessen reactivity to fire fighting-related psychological stress.

The results for stress reactivity run counter to those found with previous investigations (Holmes, 1993). In general, previous findings have indicated no difference in stress reactivity between groups when controlling for baseline values. These results may be due to the differences in method of stress induction. When a fire fighter is making decisions similar to those in the Strategy and Tactics Drill, they are dependent on their level of physical fitness to carry out these decisions. As a result, fit individuals may make more confident decisions and perceive less stress than their less-fit counterparts, reducing the relative demands of the situation. It may be that exercise training is a useful tool to reduce relative stress reactivity only when physical fitness is perceived as an important factor in dealing with situational demands, as is the case of fighting fires. This interpretation fits within Lazarus and Folkman's (1984) concept of primary and secondary appraisals of stress. Primary appraisal concerns the initial perception of threat, that is, a consideration of the demands of the situation. Secondary appraisal concerns the person's adaptive capacity, that is, their perceived ability to meet those demands. Differences in fitness are not likely to impact primary appraisal of the threat of the situation; regardless of fitness, fire fighters are required to perform physically challenging tasks (e.g., forcibly entering buildings, manning hoses, etc.). Instead, fitness may be viewed as a coping resource for those challenges that demand physical work. Because fire fighting performance is directly impacted by fitness (Ellam et al., 1994), exercise may be particularly beneficial for fire fighters in reducing physical responses to job-related psychological stress. As a result, future studies should be designed to assess the appraisal process, as well as to compare challenges with varying dependencies on fitness for performance.

It has also been suggested that the stress-buffering effects of exercise training will be limited to those tasks with which the participant is experienced (Sothman et al., 1996). According to the cross-stressor adaptation hypothesis, exercise training will result in a sympathetic nervous system adaptation such that the catecholamine response will be enhanced for a novel challenge but be diminished for familiar challenges. The Strategy and Tactics Drill was selected as the source of stress because it simulates the decision process that occurs when fighting fires. As a result, it is a task that is more familiar to fire fighters than the novel tasks that are generally employed in stress research (e.g., Stroop, mental arithmetic, etc.). As a result, future studies should be designed to compare challenges with varying levels of familiarity.

This experiment also utilized a novel training mode and regimen. One of the mechanisms by which exercise has been hypothesized to impact psychological health is the "mastery hypothesis" (Gauvin & Brawley, 1993). This theory stipulates that exercise provides individuals with an opportunity to conquer challenges and increase feelings of competency as they learn and perfect a new skill. Such experiences have been suggested to underlie the impact of exercise on self-esteem (Sonstroem & Morgan, 1989). In the present study, the LCD display on the rowing ergometer gave the participants immediate feedback during their exercise and tangible evidence of their improvement over the course of training. This feedback, coupled with the more subjective feeling of increased comfort with a novel mode of exercise, may have provided the training group with a sense of accomplishment and increased self-esteem. If the feeling of accomplishment gained from rowing can be generalized to other challenges (e.g., fire-related psychological stress), then the stress response may be diminished. Unfortunately, these constructs were not assessed in the present experiment. Future researchers should examine changes in self-efficacy and self-esteem to evaluate their relationship to changes in stress reactivity over the course of exercise training.

The physical demands of fire fighting are well established (Davis & Dotson, 1978; Duncan, Gardner, & Barnard; 1979; Gledhill & Jamnik, 1992). Given these demands, maintaining a consistent exercise program has long been suggested to maintain fire fighting performance (Brownlie et al., 1985; Sothman et al., 1990). These data suggest that exercise not only aids fire fighters in meeting the physical demands of their profession, but may aid in meeting the psychological demands as well. This point is made even stronger by the generalizability of the design. Not only was the sample drawn from a professional population, but the source of stress was directly relevant to the work of fire fighters. As a result, these data suggest that rowing may be a useful addition to the training regimen of fire fighters.

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