Available online at www.sciencedirect.com
ScienceDirect
Journal of Psychiatric Research 43 (2009) 446–454
JOURNAL OF PSYCHIATRIC RESEARCH
www.elsevier.com/locate/jpsychires

The effects of acute exercise on CO_2 challenge reactivity

Jasper A.J. Smits [a,*], Alicia E. Meuret [a], Michael J. Zvolensky [b], David Rosenfield [a], Anke Seidel [a]

[a] Department of Psychology, Southern Methodist University, Dedman College, P.O. Box 750442, Dallas, TX 75275, United States
[b] Department of Psychology, University of Vermont, United States

Received 19 March 2008; received in revised form 22 May 2008; accepted 27 May 2008

Abstract

The present study examined the effects of acute exercise on anxiogenic responding to 65% O_2/35% CO_2 challenge. Participants ($N = 92$) were 51 female and 41 male volunteers ranging in age from 17 to 24 ($M = 19.43$, SD = 1.31). Participants had no history of panic attacks and were randomized to moderate treadmill exercise (i.e., 70% of HR_{max}) or quiet rest prior to taking a single vital capacity inhalation of 35% CO_2/65% O_2. Gender and measures of negative affectivity and anxiety sensitivity were included in the design as control variables. Results indicated participants who exercised prior to challenge showed significantly reduced reactivity compared to their counterparts who rested prior to challenge. Importantly, the effect sizes for the advantage of exercise over rest remained in the medium to large range (i.e., partial $\eta^2 > .07$) after controlling for the effects of gender, anxiety sensitivity, and negative affectivity. These findings are the first to demonstrate that the anti-panic effects of exercise are unique from, and cannot be better explained by, established risk factors of CO_2 challenge reactivity.

Keywords: Exercise; Anxiety; Panic; Anxiety sensitivity; Biological challenge; Carbon dioxide

1. Introduction

Findings from initial clinical trials point to the efficacy of aerobic exercise for the treatment of panic disorder (Broocks et al., 1998; Martinsen et al., 1989). It has been proposed that aerobic exercise may exert its effects on panic disorder symptoms, in part, by reducing fear of somatic arousal (Broocks et al., 1998; Otto et al., 2007; Smits et al., 2007). Specifically, aerobic exercise provides exposure to feared interoceptive cues (e.g., racing heart, rapid breathing, sweating), thereby allowing fears to dissipate (extinguish). Evidence consistent with this mediational hypothesis comes from cross-sectional work indicating that physical inactivity is associated with greater anxiety about bodily sensations (i.e., anxiety sensitivity) both in undergraduate students (McWilliams and Asmundson, 2001) and individuals suffering from panic disorder (Smits and Zvolensky, 2006). More direct evidence comes from a series of randomized controlled (prospective) studies evaluating the efficacy of exercise for individuals with clinical levels of anxiety sensitivity (Broman-Fulks et al., 2004; Broman-Fulks and Storey, 2008; Smits et al., in press). These experiments have demonstrated that six brief sessions of moderate intensity exercise (i.e., 70% of maximal heart rate [HR_{max}]) yield significantly greater reductions in anxiety sensitivity compared to a waitlist control or placebo (i.e., low intensity exercise). Furthermore, the improvements in fear of anxiety and related bodily sensations observed with exercise tend to precede subsequent reductions in anxiety.

Previous research demonstrates that biological challenges paradigms are useful for evaluating cognitive theories of panic disorder (Schmidt et al., 1996; Schmidt et al., 1997; Zvolensky and Eifert, 2000). Indeed, these challenges (e.g., sodium lactate infusion, inhalation of high concentrations of CO_2, administration of cholecystokinin tetrapeptide [CCK_4]) have shown to reliably induce the intense

* Corresponding author. Tel.: +1 214 768 4125; fax: +1 214 768 3910.
E-mail address: jsmits@smu.edu (J.A.J. Smits).

0022-3956/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jpsychires.2008.05.009

autonomic arousal characteristic of anxiety states such as panic (Bradwejn, 1993; Liebowitz et al., 1984a; Papp et al., 1993), and as such, serve as a working model for the phenomenology of panic disorder (McNally, 1999). Consistent with theoretical accounts that emphasize the role of fear of anxiety and related (interoceptive) sensations in the onset and maintenance of panic disorder (Bouton et al., 2001; Clark, 1986; McNally, 1990), numerous studies have shown that anxiety sensitivity predicts the degree of anxious responding to biological challenges (Beck et al., 1996; Brown et al., 2003; Feldner et al., 2006; Rapee et al., 1992; Schmidt et al., 1997), even after controlling for negative affectivity (Zinbarg et al., 2001) and behavioral inhibition (Zvolensky et al., 2001); this anxiety sensitivity-challenge relationship was not observed in two studies, possibly due to a truncated range of variability in levels of anxiety sensitivity (Koszycki and Bradwejn, 2001; Struzik et al., 2004). Evidence also suggests that the reduced anxiogenic responding to biological challenges that occurs with successful cognitive-behavioral treatment of panic disorder (Gorman et al., 2004; Shear et al., 1991) may be mediated by reductions in fear of somatic arousal (Schmidt et al., 1997). Accordingly, if the mechanism of change underlying exercise interventions for panic disorder indeed resembles that of cognitive-behavioral interventions (i.e., reduction in fear of somatic arousal; Smits et al., 2004), exercise of moderate intensity should theoretically reduce anxiogenic responding to biological challenge.

To date, three controlled studies have investigated the effects of exercise on emotional responding to biological challenge (Esquivel et al., 2008, 2002; Ströhle et al., 2005). Esquivel et al. (2002) randomized 20 healthy volunteers to complete exercise or minimal activity prior to taking a single vital capacity inhalation of 35% CO_2/65% O_2. Exercise involved cycling on a bicycle ergometer with increasing workload to reach >6 mmol/L of blood lactate concentration, whereas minimal activity involved cycling on the ergometer with continuous (low) workload. Participants completed 12 min of physical activity and the two conditions showed significant differences in blood lactate concentration. Participants who exercised reported significantly reduced challenge reactivity in terms of panic symptoms relative to those in the control condition (Cohen's $d = 1.25$). Differences in anxiety responding were in the hypothesized direction, but only approached statistical significance ($d = .41$). In a separate study, Ströhle et al. (2005) randomly assigned 15 healthy participants to 30 min of treadmill exercise at 70% of maximum oxygen consumption or 30 min of quiet rest prior to receiving an injection of 50 μg of CCK_4. Results showed statistically significant and moderate to large differences (ds > .65) between participants in the exercise and control conditions with respect to CCK_4 induced panic attacks, panic symptoms, and anxiety. In an attempt to extend the findings of these early studies, Esquivel et al. (2008) recently examined the effects of acute exercise on emotional responding to biological challenge among 18 participants with a diagnosis of panic disorder. Using a similar protocol to that employed in their earlier study, they found that moderate to hard exercise (i.e., up to 15 min of cycling at 80–90% of HR_{max}) was associated with reduced CO_2 reactivity (panic attacks, panic symptoms, and anxiety) relative to very light exercise. Effect sizes observed in this study were large (ds > 1.0).

Although promising, extant biological challenge-exercise studies are limited in at least three key respects. First, it is possible that the previously documented exercise effects are attributable to other known risk factors for challenge reactivity. That is, as of yet, there is a lack of empirical evidence that acute exercise incrementally predicts reduced levels of anxiogenic responding to interoceptive sensations above and beyond pre-existing fears of the negative consequences of such stimuli (i.e., anxiety sensitivity), a history of panic attacks (Lynch et al., 1992), or a generalized tendency to react with emotionality to life events (negative affectivity; Hayward et al., 2000). Although previous studies employed randomized controlled designs, sample sizes were small and the measurement or inclusion of these predictor variables was omitted. Hsu (1989) has shown that studies with small sample sizes (such as the 18–20 participants in these previous investigations) have a high probability (53–72% in these previous investigations) of group differences on at least one "nuisance variable" even if participants are randomly assigned to groups. Accordingly, we cannot be confident that the exercise effect could not be better or largely explained by these established risk factors for anxiogenic responsivity. Second, it has not been clear whether the exercise-fear dampening effects to somatic perturbation are similarly evident among males and females. Indeed, there are well-established differences in fear reactivity to bodily sensations, with females compared to males showing greater responding (Kelly et al., 2006). It is not clear whether exercise anxiolysis varies as a function of gender. Survey studies have yielded mixed results, with some reporting a stronger relationship between physical activity and reduced anxiety among women compared to men (Stephens, 1988), while others report a stronger relationship for men relative to women (Bhui and Fletcher, 2000) or no differences based on gender (Schmitz et al., 2004). Investigations of the effects of acute exercise on anxiety have not carefully considered the potentially moderating effects of gender. It is important therefore to empirically evaluate whether females and males are affected equally by acute exercise of moderate intensity in relation to anxious and fearful responding to panic-relevant bodily sensations. And finally, each of the past studies relied on relatively small sample sizes (i.e., Ns < 20). Thus, confidence in a moderate exercise dampening effect for anxious and fearful responding to bodily sensations, both in regard to generalizability and stability of effect size, would be strengthened with replication and extension in a larger sample than in past work.