Effects of Emotional Exposure on State Anxiety after Acute Exercise

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ABSTRACT

SMITH, J. C. Effects of Emotional Exposure on State Anxiety after Acute Exercise. *Med. Sci. Sports Exerc.*, Vol. 45, No. 2, pp. 372–378, 2013. **Purpose**: Despite the well-known anxiolytic effect of acute exercise, it is unknown if anxiety reductions after acute exercise conditions survive in the face of a subsequently experienced arousing emotional exposure. The purpose of this study was to compare the effects of moderate-intensity cycle ergometer exercise to a seated rest control condition on state anxiety symptoms after exposure to a variety of highly arousing pleasant and unpleasant stimuli. **Methods**: Thirty-seven healthy and normally physically active young adults completed two conditions on separate days: 1) 30 min of seated rest and 2) 30 min of moderate-intensity cycle ergometer exercise (RPE = 13; "somewhat hard"). After each condition, participants viewed 90 arousing pleasant, unpleasant, and neutral pictures from the International Affective Picture System for 30 min. State anxiety was measured before and 15 min after each condition, and again after exposure to the affective pictures. **Results**: State anxiety significantly decreased from baseline to after the exercise and seated rest conditions ($P = 0.003$). After the emotional picture-viewing period, state anxiety significantly increased to baseline values after the seated rest condition ($P = 0.001$) but remained reduced after the exercise condition. **Conclusion**: These findings suggest that the anxiolytic effects of acute exercise may be resistant to the potentially detrimental effects on mood after exposure to arousing emotional stimuli.
Key Words: AFFECT, EMOTION, IAPS, MOOD, PHYSICAL ACTIVITY, QUIET REST

The effect of a single session of exercise to improve mood and reduce subjective symptoms of anxiety in healthy nonanxious adults has been well established (23,24,26–28). However, in many investigations, anxiety reductions after acute exercise have been shown to be similar to the effect of a "quiet rest" or similar control condition (8,17,30). Although the anxiolytic effects of acute exercise have been shown to persist longer compared with quiet rest conditions (8), this difference has not been observed consistently (17,30).

The efficacy of quiet rest conditions to improve mood suggests there may be a common anxiety-reducing factor present during exercise and rest conditions, such as a time out from stressors or other worries (1,6). Other studies have modified the exercise and rest conditions through manipulations of body temperature (44) or caffeine ingestion (25,45) and have shown that the anxiolytic effects of exercise survive these manipulations, whereas quiet rest conditions do not. This suggests a specific yet undefined effect of acute exercise, not evoked during quiet rest, which promotes durability of its anxiolytic effect. Although adaptations to repeated bouts of exercise stress have been purported to provide protection against other nonexercise stressors (i.e., the cross-stressor adaptation hypothesis [36]), these effects have been shown to be quite heterogeneous and dependent on the type of laboratory stressor used, among other factors (19). This literature has focused on the effects of exercise training or cross-sectional differences in fitness, not acute exercise, in response to laboratory stress tasks (e.g., mental arithmetic, cold-water immersion, and Stroop color-word conflict task) that lack face validity for the types of emotional stressors encountered in daily life. A key unanswered question is whether acute exercise confers short-term protection, after its cessation, against typically experienced psychological stressors or emotional provocation.

As described by Lang and Bradley (21), emotions can be defined as "action dispositions." As such, the physiological and neural systems that govern emotional responsiveness overlap considerably with the physiological and neural systems that govern muscular activation and motor behavior. Exposure to a variety of affective picture stimuli has been shown to evoke changes in autonomic nervous system activation, including sympathetic activation and cardiac-vagal withdrawal (21), which also occur during acute exercise. Furthermore, Smith et al. (32) have reported that reactivity during repeated exposure to emotional stimuli is sensitive to self-reported state anxiety. This suggests that anxiety-reducing

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treatments, such as acute exercise or quiet rest, may modify the cumulative effects of exposure to emotionally arousing stimuli (10).

Very little is known, however, regarding whether acute exercise provides subsequent protection against the potentially stressful effects related to exposure to arousing emotional stimuli. Smith et al. (34) reported that acute exercise did not alter emotional reactivity during the viewing of pleasant, neutral, and unpleasant pictures. In that study, state anxiety was assessed after the exercise and rest conditions before exposure to the emotional pictures, but not after picture viewing. Thus, it is not clear if state anxiety after exercise remains reduced when exposed to arousing emotional stimuli. The aim of this study was to compare the effects of moderate-intensity exercise to a seated rest control condition on state anxiety symptoms after exposure to a variety of highly arousing pleasant and unpleasant stimuli. It was hypothesized that state anxiety would be reduced after both exercise and seated rest. Because acute exercise actively engages the physiological systems involved in emotional responsiveness, it was further hypothesized that anxiety reductions would persist after exposure to emotional stimuli for the exercise but not the seated rest condition.

METHODS

Participants. Thirty-seven healthy college students (22 men and 15 women) volunteered to complete the study. One male participant was excluded from the analysis because of missing data. The institutional review board approved the study, and written informed consent was obtained from each participant. Participants were recruited from undergraduate courses but were not offered extra course credit or payment for participation. The exclusion criteria included left-handedness, current use of antidepressant or antianxiety medication, or contraindications to exercise (e.g., heart disease, high blood pressure, and high cholesterol). No participants were excluded based on these exclusion criteria. The participants were within the normal range on trait anxiety, which measures the proneness to experience anxiety symptoms (mean ± SD, 45.7 ± 3.4; range, 38–54), and reported normal (minimal to mild) levels of depression symptoms (mean ± SD, 4.4 ± 4.7; range, 0–18).

Design. A within-subject experimental design was used. Each participant completed two conditions (seated quiet rest and moderate-intensity cycle ergometer exercise) and afterward viewed emotional pictures from the International Affective Picture System (IAPS) (22). The primary dependent variable was state anxiety score, measured before and after each condition and after affective picture viewing. Testing occurred on two different days within a 7-d period. The order of condition was counterbalanced across subjects, and two different picture orders were counterbalanced across testing day and condition. A power analysis based on an expected moderate correlation between repeated measures (r = 0.6) and a small effect (d = 0.25) for the interaction between condition (exercise vs seated rest) and time (pre-, post-, and post-picture viewing) detected at an α of 0.05 indicated a sample size of 36 provides statistical power of 0.95 (16).

Procedures. Participants were instructed to arrive each day prepared to exercise. On the first day, participants completed written informed consent, a health history questionnaire, the Beck Depression Inventory II (4), and the State-Trait Anxiety Inventory (STAI) (39) in a sound-attenuated and temperature-controlled room (~24°C ± 1°C). Then participants were taken to a different nearby room where they were informed of the experimental condition that would be performed. For the exercise condition, participants pedaled an electronically braked cycle ergometer (Corival, Lode B.V., Groningen, The Netherlands). After the seat height was adjusted, standardized instructions were provided regarding the use of the RPE scale (5,7). A 5-min warm-up and cool-down was completed at 50 W. During the exercise condition, the participant pedaled for 30 min at an intensity that corresponded with an RPE of 13 (associated with the verbal anchor "somewhat hard"). The participant was free to adjust the resistance to match the perception of "somewhat hard" throughout the 30-min session. Pedal cadence was maintained between 70 and 90 rpm. Heart rate (Polar Electro, Kempele, Finland), RPE, and work rate were recorded every 5 min. During the seated rest condition, the same procedures were followed, but the participant sat on the bike for 40 min and did not pedal.

After the exercise or rest condition, the participant was provided water *ad libitum* and returned to the sound-attenuated room. Fifteen minutes after the completion of the exercise or rest condition, participants completed form Y1 (state anxiety) of the STAI. The STAI-Y1 instrument is widely regarded as a reliable (2,39) (internal consistency α = 0.92; test–retest r = 0.88) and valid measure of state anxiety (39,42) defined as "a temporal cross-section in the emotional stream of life of a person, consisting of subjective feelings of tension, apprehension, nervousness, and worry, and activation or arousal of the autonomic nervous system" (37). The STAI has been used in many different disciplines (more than 3000 publications, translated to 30 languages [38]) and is the most cited anxiety instrument in the context of exercise (26,43). Participants then viewed 90 pictures from the IAPS (22) on a 14-inch color monitor located approximately 1 m away. The IAPS has been used worldwide as a set of visual stimuli to induce emotion in a laboratory setting. Repeated exposure to unpleasant IAPS pictures has been shown to induce a shift in mood and to be sensitive to baseline state anxiety (32). Among the 90 pictures used, 30 were pleasant (15 erotica and 15 babies, families, and cute animals), 30 were neutral (15 neutral people and 15 neutral objects and scenes), and 30 were unpleasant (15 threat and 15 mutilation) based on normative ratings of valence (for normative ratings, see Table 1 and Supplemental Digital Content 1, http://links.lww.com/MSS/A192. Appendix [IAPS stimuli] for IAPS numbers). The 90 pictures were arranged in

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three blocks of 30; each block contained 10 pictures from each valence category. The order within each block was pseudorandom in that no more than two pictures from the same category could appear consecutively. Two different picture orders were constructed and counterbalanced across testing day and experimental condition. Each picture was shown for 4 s and was followed by a 12-, 14-, or 16-s inter-picture interval (mean, 14 s), which consisted of a centrally located fixation cross. The total picture-viewing time, including brief breaks between each picture block, was approximately 30 min. Participants were instructed to look at each picture the entire time it was on the monitor and to subjectively categorize each picture as pleasant, neutral, or unpleasant using (with their right hand) a three-button response pad resting on their lap. The purpose of the picture categorization task was to promote visual attention to the pictures. Immediately after the picture-viewing task (~50 min after the cessation of the exercise and rest conditions), participants completed form Y1 of the STAI. Upon completion of the study procedures on day 2, participants rated each of the 90 pictures (hard copy, one picture per page in a standard order, self-paced) using the SAM.

Data analysis. State anxiety scores were analyzed using a 2 (condition: exercise and seated rest) × 3 (time: preexercise, postexercise, and postpicture viewing) repeated-measures ANOVA. Follow-up contrasts were computed using a general linear model and paired samples *t*-tests. There were no violations of the sphericity assumption as indicated by the Mauchly test of sphericity (all $P > 0.2$). Preliminary analysis indicated no significant effects of sex, so sex was not included as a factor in the analysis.

RESULTS

The characteristics of the sample and subjective valence and arousal ratings of the pictures are shown in Table 1. Physiologic and subjective responses associated with each condition across the different measurement periods are shown in Table 2. As expected, heart rate was significantly greater during and 15 min after the exercise compared with the rest condition. In addition, ratings of perceived exertion, leg muscle pain, and affective arousal were greater during exercise compared with during seated rest. Subjective ratings of pleasantness were greater before and 15 min after exercise compared with seated rest (see Table 2).

There were no differences in state anxiety scores before each condition, $F(1,35) = 0.266$, $P = 0.609$, $h_p^2 = 0.008$. There was a condition × time interaction, $F(2, 70) = 3.029$, $P = 0.055$, $\eta_p^2 = 0.080$, and a main effect for time, $F(2,70) = 4.170$, $P = 0.019$, $\eta_p^2 = 0.106$. Follow-up contrasts indicated state anxiety significantly decreased from before to 15 min after both conditions, $F(1,35) = 10.003$, $P = 0.003$, $\eta_p^2 = 0.222$. However, in comparison to the 15-min post-condition measurement (before exposure to emotion) state anxiety remained decreased after emotional exposure for the exercise condition ($P = 0.842$) and significantly increased after emotional exposure for the seated rest condition ($P = 0.001$) (see Fig. 1). Furthermore, the only significant difference in state anxiety between the exercise and seated rest conditions occurred after exposure to emotional pictures when state anxiety was significantly lower after exercise compared with seated rest, $F(1,35) = 9.472$, $P = 0.004$, $\eta_p^2 = 0.213$.

DISCUSSION

There have been few investigations regarding how acute exercise may affect responses to a subsequent exposure to emotional stimuli. The novel finding of the current study was that state anxiety was reduced after 30 min of moderate-intensity exercise and remained reduced after the viewing of arousing emotional pictures. In contrast, the anxiolytic effect of quiet rest did not persist but rather returned to baseline after emotional picture viewing.

This work extends the findings reported by Smith et al. (34) in which they found that neither low-intensity nor moderate-intensity acute exercise modified facial EMG responses during affective picture viewing. Electroencephalographic (EEG) responses during affective picture viewing were also reported to be unaffected by acute exercise or seated rest (10). Although state anxiety was reduced after

TABLE 1. Participant characteristics and affective ratings of picture stimuli ($N = 36$).[a]

	Current Sample		Comparative Data	
Variable	Mean	SD	Mean	SD
Age	22.6	3.3	–	–
Trait anxiety (STAI-Y2)	45.7	3.4	39.6[b]	9.8
Depression symptoms (BDI-II)	4.4	4.7	9.1[c]	7.6
Leisure time physical activity (arbitrary units)	51.3	20.8	45.8[d]	NR
Pleasant picture valence ratings (SAM)	6.73	0.94	7.15[e]	1.68
Neutral picture valence ratings (SAM)	5.03	0.21	5.05[e]	1.28
Unpleasant picture valence ratings (SAM)	2.07	0.96	2.27[e]	1.55
Pleasant picture arousal ratings (SAM)	3.99	1.96	5.38[e]	2.24
Neutral picture arousal ratings (SAM)	2.33	1.43	3.14[e]	1.93
Unpleasant picture arousal ratings (SAM)	4.31	2.15	6.70[e]	2.15

[a] Affective ratings of pictures were missing for two subjects.
[b] Based on normative data from 855 college-age students (531 women and 324 men) (39).
[c] Based on normative data from 1022 college-age students (531 women and 324 men) (12).
[d] Based on normative data from 306 healthy adults (163 men and 143 women; mean age, 30.7 yr), with a mean ± SD VO_{2max} of 39.6 ± 6.0 $mL \cdot kg^{-1} \cdot min^{-1}$ (18).
[e] Based on normative data from healthy college students (22).
BDI-II, Beck Depression Inventory II; STAI-Y2, State-Trait Anxiety Inventory-Form Y2; NR, not reported; SAM, Self-Assessment Manikin, 1 to 9 scale (20).

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TABLE 2. Physiological and subjective responses before (Pre), during, 15 min after (Post), and after emotional picture viewing (After pictures) for the exercise and rest conditions.

	Exercise		Rest		Comparison
Variable	Mean	SD	Mean	SD	*P*
Work (W)	83.4	29.1	–	–	–
Heart rate (bpm)					
Pre	86.8	18.8	86.9	18.0	NS
During	136.9	15.9	83.0	12.6	<0.001
Post	83.3	12.0	74.1	14.6	<0.001
After pictures	76.9	12.4	72.8	12.4	NS
RPE (scale, 6–20)					
Pre	6.4	1.1	6.0	0.2	NS
During	13.0	0.5	6.1	0.2	<0.001
Post	6.2	0.9	6.0	0.2	NS
After pictures	6.1	0.3	6.1	0.4	NS
Leg pain (scale, 0–10)					
Pre	0.1	0.3	0.0	0.1	NS
During	1.5	1.2	0.1	0.3	<0.001
Post	0.1	0.4	0.1	0.2	NS
After pictures	0.1	0.4	0.0	0.1	NS
Pleasantness (scale, 1–9)					
Pre	7.5	1.6	6.9	1.9	NS
During	7.3	1.4	7.1	1.5	NS
Post	7.5	1.5	6.9	1.5	NS
After pictures	6.6	2.0	6.4	1.7	NS
Arousal (scale, 1–9)					
Pre	3.8	2.0	3.5	2.0	NS
During	5.3	1.7	3.4	1.9	<0.001
Post	3.9	2.2	3.4	1.9	NS
After pictures	2.8	1.8	3.2	1.9	NS

P value reflects the comparison between conditions within each variable (Bonferroni adjusted, $P < 0.0125$).
NS, not statistically significant.

both the exercise and the seated rest conditions in the Smith et al. (34) study, they did not measure state anxiety after exposure to the emotional stimuli. In the study by Crabbe et al. (10), ratings of picture pleasantness were unaffected by acute exercise; however, ratings of arousal during the viewing of unpleasant pictures were lower after exercise compared with rest, suggesting that acute exercise may have affected subjective responses specific to unpleasant pictures. In the current study, subjective ratings of the picture stimuli occurred only once at the end of the study after the pictures had been viewed twice previously. Thus, it was not possible, in a novel context, to determine whether there were differences between exercise and rest on arousal or pleasantness ratings of the pictures. Another recent study reported that attentional bias toward pleasant and unpleasant IAPS pictures was not changed after acute exercise (3), suggesting that subjective appraisal of specific single instances of emotional stimuli is unaltered after the exercise has ended. The failure of acute exercise to alter psychophysiological responsiveness during the actual viewing of an arousing pleasant or unpleasant stimulus (10,34) suggests that the neural systems that process and respond to specific instances of emotion remain undisturbed. Despite intact emotional responsiveness to briefly presented visual stimuli, the current study suggests that acute exercise may protect one from the cumulative effects of exposure to a variety of arousing emotional stimuli (32).

It is not yet clear, however, how the neural systems that process emotional stimuli are affected during moderate-intensity acute exercise. Low-intensity exercise (40% of maximal capacity) did not alter emotional responsiveness to IAPS pictures (33). However, it has been recently reported that visual attentional bias was altered during moderate-intensity exercise (41). Using the dot-probe task, it was shown that attentional bias shifted (from a neutral bias at rest) toward pleasant faces and away from unpleasant faces during moderate-intensity exercise similar to that used in the current study. This suggests that the engagement of the appetitive motivational system may be enhanced and the engagement of the aversive motivational system may be inhibited during moderate-intensity exercise. However, it is not clear if these effects on the visual attention system may persist into the postexercise period (3,33) or if acute exercise modifies attentional bias among people diagnosed with affective or anxiety disorders (41).

There is evidence to support the hypothesis that exercise may promote a persistence of postexercise anxiety reduction and a resiliency to perturbation by emotional stressors (9). For example, when the time out during exercise was blocked by having high-anxious women study academic material while they exercised, their anxiety scores still decreased by a greater magnitude after exercise compared with when they studied during a quiet rest condition (6). It has also been shown that exercise performed after caffeine ingestion (which leads to increased state anxiety) results in anxiety reduction, an effect not observed after quiet rest conditions (25,45).

There are several studies that have examined the effect of acute exercise on anxiety and panic-like symptoms in response to interoceptive sensations induced during a biological

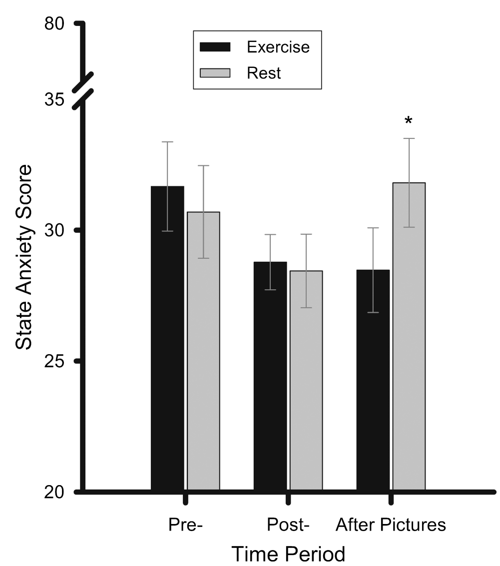

FIGURE 1—State anxiety scores before (Pre) and after (Post) the exercise and seated rest conditions and after the picture-viewing session (After Pictures). The mean ± SD state anxiety scores were as follows: preexercise, 31.7 ± 10.2; prerest, 30.7 ± 10.6; postexercise, 28.8 ± 6.3; postrest, 28.4 ± 8.4; after pictures exercise, 28.5 ± 9.7; after pictures rest, 31.8 ± 10.2. Error bars = SEM. *Significant difference between the exercise and seated rest condition (*P* = 0.004).

APPLIED SCIENCES

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challenge. In two studies, a 35% CO_2 mixture with oxygen was inhaled after acute exercise compared with after a control condition in healthy adults (15,35). Panic-like symptoms after the CO_2 inhalation were attenuated after exercise compared with after rest (15), and these effects were also shown to be independent of anxiety sensitivity, negative affectivity, and cardiorespiratory fitness (35). Similar results were reported by Ströhle et al. (40), in which panic-like symptoms were reduced when cholecystokinin tetrapeptide (CCK_4) was administered to healthy adults after acute exercise compared with after a rest control condition. It has also been shown that the anxiogenic effects of a 35% CO_2 challenge are reduced after acute exercise in patients diagnosed with panic disorder (14). There are two important distinctions between this previous work and the current study. First, state anxiety scores have not been reported after exercise or the physiological challenge; rather, panic-like symptoms or fear have been assessed, which are considered to be different from anxiety (11). Second, air enriched with CO_2 (or injection of CCK_4) is a strong anxiogenic stimulus and when inhaled is a substantial threat to homeostasis. Previous acute exercise did not prevent fear or panic-like symptoms during a CO_2 challenge, but it did lessen its effect. Although highly arousing affective pictures do not induce the large-scale interoceptive sensations and biological challenge that occur while breathing 35% CO_2, emotional picture viewing has been shown to affect peripheral psychophysiological systems and neural indices of both defensive and appetitive activation (21,32). An emotional picture-viewing paradigm may be more representative of the breadth of repeated emotional challenges people face on a daily basis.

The timing of the anxiety measurements postexercise was based on two factors: 1) the largest effects of anxiety reductions after acute exercise have been observed 15–20 min after the cessation of exercise, not immediately after exercise (26,28); and 2) because physiological arousal is theorized to affect reactions to emotional stimuli (21), the 15-min delay also served to equate subjective arousal between the exercise and the control conditions (as shown in Table 2). The study was designed to provide exposure to emotion at a time when anxiety had been reduced and when arousal was equivalent between conditions. In this regard, any subsequent change in anxiety (or lack thereof) could not be attributable to differences in physiological arousal during emotion exposure, but only to the method by which the anxiety reduction had been realized. The similarity between the exercise and rest condition in this 15-min break preserved the internal validity of the acute exercise manipulation. If the anxiolytic effects of exercise provide a buffer against emotion provocation, as suggested here, and are to be considered useful for the management of anxiety symptoms in the face of ongoing exposure to emotional events in our environment, then one might expect these effects would persist after the exercise has ended. In this case, the anxiety reduction was maintained approximately 1 h after exercise, which is consistent with previous reports and reviews (28,31). It will be important for future studies to examine when these effects may dissipate and if these effects are observed in those diagnosed with anxiety disorders.

The STAI form Y1 was used as the measure of the multidimensional and multisystem construct "state anxiety" because this instrument has been shown repeatedly to demonstrate good reliability, a stable factor structure, and exceptional construct validity evidenced by numerous experimental manipulations and cross-sectional comparisons of clinically diagnosed patient groups (39,42). The recent work by Vautier and Pohl (42) confirmed the original four-factor structure of the STAI (state anxiety present, state anxiety absent, trait anxiety present, and trait anxiety absent). Furthermore, they confirmed that both the state and trait anxiety forms (Y1 and Y2, respectively) measure unified bipolar constructs, not separate constructs such as anxiety and serenity or somatic and cognitive anxiety. This is consistent with the criteria for diagnosis of anxiety disorders, which describes anxiety as an amalgamated multidimensional construct affecting both mind and body (13). Because of the large interindividual variability in state anxiety scores across time, the use of form Y1 to measure state anxiety change were shown by Vautier and Pohl (42) to be highly reliable. Thus, investigators and clinicians should be encouraged to continue the use of the STAI to measure changes in state anxiety in the contexts of exercise and physical activity (29).

There are several limitations of the current study. An intermixed presentation of pleasant, neutral, and unpleasant pictures was used, so it is not clear which emotional content could be more important to the effects observed. The study by Crabbe et al. (10) suggests that subjective arousal during unpleasant picture viewing may be reduced after exercise. The work by Tian and Smith (41), however, suggests visual attention toward pleasant and away from unpleasant pictures may occur during exercise. Future studies should confirm these findings and further examine distinctions between emotion processing during and after exercise as well as the effects of acute exercise on anxiety after a sustained presentation of specific affective content (32). Second, unlike previous studies that have used a "lazy boy" chair, the seated rest condition was conducted on the bike, which provided a control condition that differed from the experimental condition only in the volitional exertion required to pedal at a moderate intensity. As noted in Table 2, other than expected differences in leg muscle pain and affective arousal between the conditions attributable to the manipulation (7,34), the affective experience was very similar between the exercise and the seated rest conditions. Consistent with the affective picture-viewing literature, subjects sat in a comfortable padded chair during picture viewing after both conditions. Thus, it is unlikely that postural or affective differences between the conditions influenced the results. Finally, the sample consisted of healthy young adults in the normal range for trait and state anxiety. This study was focused on the issue of the quality, not quantity, of the anxiety reduction after experimental exercise and rest conditions. The innovation of this work in comparison with the body of literature is a

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manipulation of exposure to a variety of typical "real-world" emotional stimuli after the anxiolytic effects occurred. This study demonstrated that the anxiolytic effects of acute exercise survive subsequent exposure to emotional stimuli, whereas the anxiolytic effects of quiet rest do not. The demonstration of this effect in normal healthy adults is important and has broad implications for public health, mental health, and the prevention of emotion-related mental disorders in the healthy adult population. However, it is not known if these effects generalize to people diagnosed with anxiety or affective disorders, to less healthy or less physically active individuals, or to older adults.

In summary, both acute moderate-intensity exercise and seated rest were shown to reduce state anxiety scores. However, when faced with a 30-min exposure to a variety of emotional stimuli, state anxiety remained reduced after exercise but increased back to baseline after the seated rest condition. This suggests that acute exercise may enhance resilience to the cumulative effects of exposure to arousing emotional stimuli.

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