



Acute effect of moderate-intensity aerobic exercise on state anxiety and anger symptoms evoked by aversive stimuli in young women: A randomized clinical trial

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ABSTRACT

Background: Aerobic exercise is widely recognized for its acute anxiolytic and mood-regulating effects, typically demonstrated in neutral emotional contexts. However, it remains unclear whether such effects are preserved when exercise is performed concurrently with emotionally aversive stimuli, a situation that more closely mirrors real-world stress conditions.

Objective: To examine whether a single session of moderate-intensity continuous aerobic exercise, performed simultaneously with exposure to aversive images, could mitigate acute symptoms of state anxiety and anger in young adult women.

Methods: In a randomized controlled design, 52 healthy women (18–40 years) attended two laboratory visits. The first visit included informed consent, health screening, anthropometric assessments, and a graded exercise test. In the second visit, participants were randomized to four groups: Neutral Control, Aversive Control, Neutral Exercise, and Aversive Exercise. During a 30-minute intervention (cycling at 64–76% maximal heart rate or quiet sitting), participants viewed neutral or aversive images from the International Affective Picture System. State anxiety and state anger were measured at baseline, immediately post-session, and at 10- and 20-minute follow-ups.

Results: A significant main effect of time was observed for both anxiety and anger ($p < 0.05$). For anxiety, symptoms increased immediately post-session but returned to baseline, with no main effect of group ($p > 0.05$) and no significant time \times group interaction ($p > 0.05$). For anger, there was a main effect of time ($p < 0.05$) and a significant time \times group interaction ($p = 0.028$), driven by an increase in anger in the Aversive Exercise group immediately post-session ($p = 0.0001$). No significant effects were detected under neutral conditions.

Conclusions: Concurrent exposure to emotionally aversive stimuli during moderate-intensity aerobic exercise does not reduce acute anxiety or anger in young women and may amplify anger responses. Emotional context may override the affective benefits typically associated with aerobic exercise.

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1. Introduction

Anxiety and anger are emotional states that play central roles in the human affective response to psychological stress and have been increasingly recognized as contributors to adverse mental and physical health outcomes when dysregulated (Gross & Jazaieri, 2014; Kuppens et al., 2010). Although typically transient, repeated or prolonged episodes of these emotions can contribute to heightened allostatic load, increasing susceptibility to mood disorders, cardiovascular disease, and other stress-related conditions (Chida & Steptoe, 2009; Slavich & Irwin, 2014). Thus, identifying effective feasible and accessible strategies to modulate acute fluctuations in negative affect is of growing importance in both clinical and non-clinical populations.

A growing body of evidence supports the acute anxiolytic and anger-reducing effects of aerobic exercise (Ensari et al., 2015; Rebar et al., 2015). These effects are thought to involve multiple neurobiological and physiological mechanisms, including modulation of the hypothalamic-pituitary-adrenal axis, increased availability of endorphins and brain-derived neurotrophic factors, and changes in cortical activation patterns associated with emotion regulation (Dishman & O'Connor, 2009; Schneider & Preckel, 2017). However, most studies have examined these outcomes in emotionally neutral contexts (Ekkekakis & Petruzzello, 1999; Ensari et al., 2015; Rebar et al., 2015). Less is known about whether the affective benefits of exercise persist when it is performed under emotionally aversive conditions, an issue of ecological validity, as real-world physical activity often occurs in emotionally charged or stressful environments, such as matches held in environments with opposing fans.

The International Affective Picture System (IAPS) reliably elicits negative effects in laboratory settings, allowing controlled induction of anxiety and anger (Bradley & Lang, 2017; Costa et al., 2022; Silva et al., 2025; Viana et al., 2021). Because real-world stressors often emerge concurrently with physical activity, examining emotional regulation strategies under these conditions provides stronger ecological validity. In this context, young women represent a particularly relevant population for this investigation due to their greater prevalence of anxiety disorders and heightened emotional reactivity (Domes et al., 2010; Nielsen et al., 2013; Sabatinelli et al., 2011) making them an especially relevant population for investigating acute emotion-regulation strategies. Given these characteristics, focusing on women allows clearer examination of how concurrent emotional and physical stressors interact (Liu et al., 2024; Nielsen et al., 2013).

When emotional and physical stressors occur simultaneously, emotionally salient stimuli may dominate attentional and regulatory resources, reducing the affective benefits typically associated with exercise (Ekkekakis & Petruzzello, 1999; Hall et al., 2007). Under such dual-load conditions, emotional salience may override exercise-induced regulatory processes (da Silva et al., 2022; Ekkekakis & Petruzzello, 1999).

To date, few studies (Hall et al., 2007; Petruzzello et al., 1991; Van Dis et al., 2020) have examined whether the psychological benefits of acute aerobic exercise are preserved when it is performed simultaneously with emotional stress exposure. While some evidence suggests that exercise can attenuate negative effects when undertaken after stress exposure (Petruzzello et al., 1991), the affective outcomes of exercising under real-time emotional challenge remain poorly understood.

Building on this perspective, our research group has investigated the interplay between emotional exposure and physical exercise. Silva et al. (2025) compared state anxiety levels after a single exergame session, a traditional continuous exercise session, and a non-exercise control in young women exposed to unpleasant stimuli. The authors found that although both dance exergame and traditional continuous exercise reduced state anxiety, these reductions were not greater than those observed in the control condition. Morais et al. (2025) examined the effects of self-selected versus prescribed moderate-intensity aerobic exercise following unpleasant image exposure in young women. They

reported that although anxiety symptoms increased after exposure to unpleasant stimuli, they decreased to a similar extent after both exercise and control sessions. However, affective responses improved only after the exercise sessions. Taken together, these findings establish a line of investigation into how women react to aversive emotional stimuli and how exercise can modulate these responses. The present study extends this trajectory by testing whether the concurrent performance of exercise and aversive exposure alter acute anxiety and anger outcomes, thereby enhancing the ecological validity of this research line.

Therefore, this study investigated whether a single session of moderate-intensity continuous aerobic exercise could protect against symptoms of state anxiety and state anger in young adult women exposed concomitantly to emotionally aversive stimuli from the IAPS during physical exercise. We hypothesized that: (1) participants exposed to aversive stimuli would show greater increases in state anxiety and anger compared to those exposed to neutral stimuli; and (2) physical exercise would attenuate these emotional responses, or faster recovery, in exercise groups compared to control groups.

2. Methods

2.1. Ethical approval

The study was approved by the Research Ethics Committee of the Federal University of Goiás (approval no. 43896821.6.0000.5083), conducted in accordance with the Declaration of Helsinki, and registered with the Brazilian Registry of Clinical Trials (RBR-6bg7xkk). All participants provided written informed consent and were informed of their right to withdraw from the study at any time without any negative consequences.

2.2. Study design

This was a randomized clinical trial designed to assess the acute effects of moderate-intensity continuous aerobic exercise on state anxiety and anger levels induced by unpleasant emotional stimuli concomitantly with exercise. All procedures were conducted at the Human Movement Assessment Laboratory of the Federal University of Goiás (Goiânia, Brazil).

The protocol consisted of two visits spaced 24–72 h apart. During the first visit, participants completed informed consent forms, screening assessments, and baseline measures, including anthropometric measurements, trait anxiety, and trait anger. A cardiopulmonary exercise test determined maximal oxygen uptake ($VO_2\text{max}$) and maximal heart rate ($HR\text{max}$).

In the second visit, participants were randomly assigned to one of four experimental groups using block randomization via www.randomizer.org, to ensure equal group sizes, to one of the four groups: (i) Neutral Control, (ii) Aversive Control, (iii) Neutral Exercise, and (iv) Aversive Exercise. Furthermore, all participants completed state anxiety (STAI-S) and state anger (STAXI-S) assessments pre-intervention and at 0-, 10- and 20-min post-intervention. Exercise sessions involved 30 min exercise at 64–76% $HR\text{max}$ (moderate intensity) in accordance with American College of Sports Medicine guidelines (Garber et al., 2011). HR and rate of perceived exertion were monitored every 5 min. The control condition involved 30 min of quiet sitting. In both exercise and control groups, the participants were exposed to unpleasant or neutral images from IAPS. To minimize external influences, sessions were conducted in a controlled environment with silence, stable room temperature, and no extraneous conversation. Notably, no medical complications arose during the experimental procedures.

2.3. Participants

Sixty-seven healthy women aged between 18 and 40 years were recruited via social media (WhatsApp and Instagram), institutional

platforms, and direct contact. Inclusion criteria included: (i) female sex; (ii) age 18–40 years; and (iii) normal or corrected-to-normal vision. Exclusion criteria comprised: (i) contraindications to exercise assessed using the Physical Activity Readiness Questionnaire (PAR-Q) (participants who answered ‘yes’ to one or more questions were excluded from the study), (ii) diagnosis of mood anxiety disorders, (iii) use of psychotropic drugs or substance abuse, (iv) illiteracy, (v) incomplete responses to any tool used in experimental protocol, and (vi) menstrual phase at time of assessment. Eleven participants were excluded for different reasons (Fig. 1). Accordingly, 56 participants met the eligibility criteria and were randomized. However, four participants were excluded after randomization because they did not complete all procedures. Therefore, the final analysis comprised 52 participants.

Women were chosen due to their higher prevalence of anxiety-related disorders compared to men (WHO, 2017). All participants provided written informed consent prior to participation. Table 1 presents descriptive characteristics of the sample. Fig. 1 presents the flowchart of recruitment and participant flow.

2.4. Experimental procedures

2.4.1. Cardiopulmonary exercise test

Participants performed a cardiopulmonary exercise test on a cycling ergometer Airbike (Assault Bike Classic, Movement, Brazil) to determine VO_2max and HRmax . The test was conducted using the VO2000

metabolic system (Medical Graphics Corporation, USA). A nasal clip was used to prevent nasal airflow and an HR monitor (Model H10, Polar, Finland) was positioned at the xiphoid process. The protocol began with a 2-min warm-up at 50 W, followed by progressive workload increases of 25 W per 2 min until volitional exhaustion (ACSM, 2018; Tsuk et al., 2019). The test was terminated when the participant was unable to maintain the required workload for 30 s (Howley et al., 1995; Wasserman et al., 2007).

The Airbike is an ergometric device that combines simultaneous upper and lower limb movements, allowing for full-body exercise. Its resistance system is based on air resistance generated by a fan activated by the user's motion. The relationship between effort and resistance is hyperbolic: the faster and harder the user moves, the greater the air resistance generated. As a result, the cadence is not constant throughout the test. For the determination of VO_2max , the data recorded in the BreezeSuite software (v6.4.1, MedGraphics, USA) were filtered using 30-s averaging. VO_2max was identified at the point where an increase in workload no longer resulted in a further increase in oxygen uptake (VO_2), characterizing a VO_2 plateau (ATS, 2002; Milani et al., 2006).

The HRmax obtained during the test was compared to the age-predicted HRmax using the Tanaka et al. equation (Tanaka et al., 2001). Although the Tanaka formula ($208 - 0.7 \times \text{age}$) was used to estimate predicted HRmax values for reference purposes, it was not employed for exercise prescription in this study. This equation is known to present substantial individual variability, with standard errors that

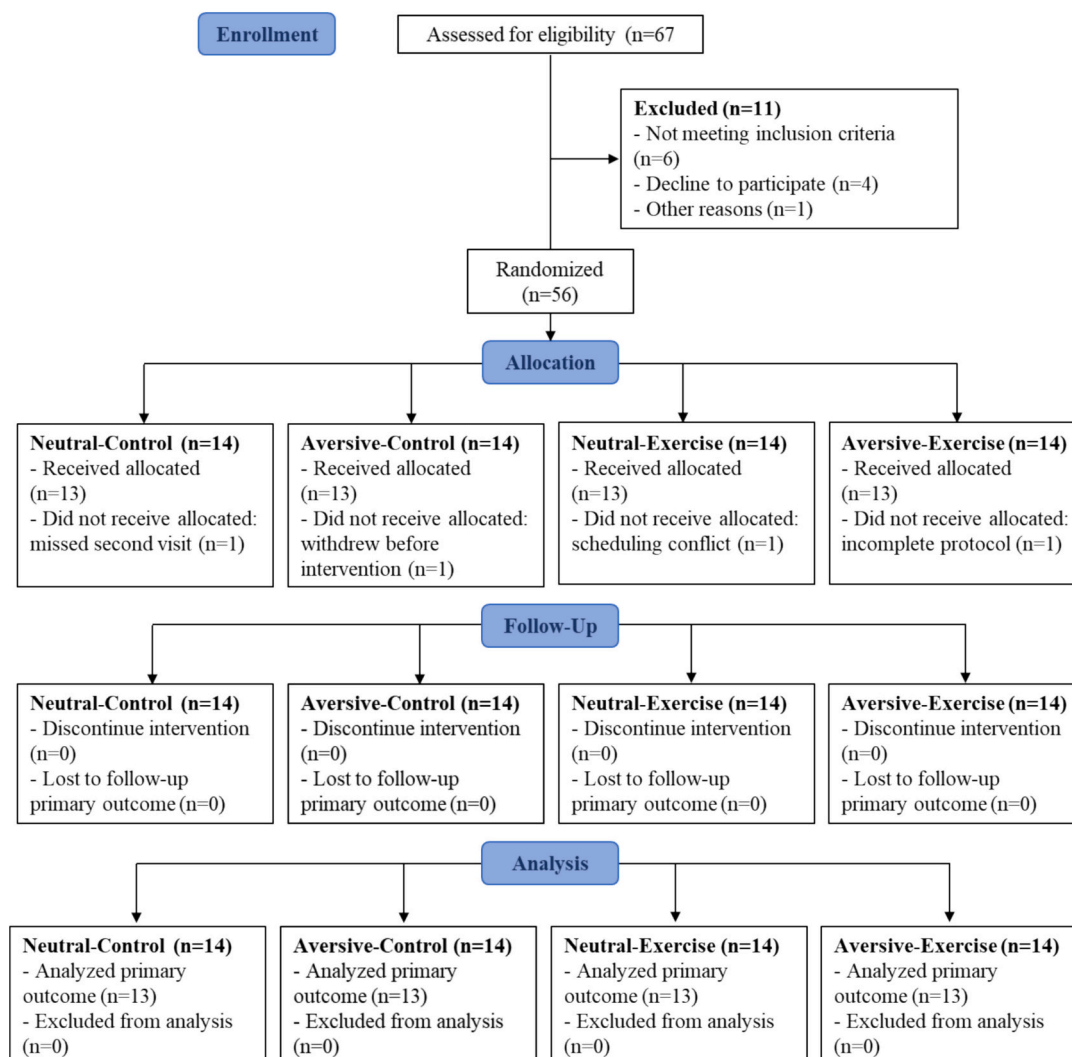


Fig. 1. Flowchart of recruitment and participant flow.

Table 1
Participant characteristics.

Variables	Control neutral (n = 13)	Control aversive (n = 13)	Exercise neutral (n = 13)	Exercise aversive (n = 13)	All samples (n = 52)	p-Value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Age (years)	24.6 ± 4.7	25.3 ± 4.9	24.4 ± 5.7	26.0 ± 7.0	25.1 ± 5.5	0.903
Body mass (kg)	61.9 ± 8.3	65.1 ± 14.0	62.4 ± 10.6	58.6 ± 10.4	62.0 ± 10.9	0.533
Height (m)	1.64 ± 0.0	1.63 ± 0.06	1.63 ± 0.0	1.61 ± 0.0	1.63 ± 0.0	0.603
BMI (kg/m ²)	22.9 ± 3.4	24.3 ± 5.0	23.3 ± 3.9	22.6 ± 4.0	23.3 ± 4.0	0.744
Trait anxiety (scores 20–80)	46.6 ± 11.8	47.3 ± 11.6	43.0 ± 10.9	45.3 ± 8.6	45.5 ± 10.6	0.758
Trait anger (scores 10–40)	23.4 ± 7.2	20.2 ± 6.6	21.1 ± 5.5	19.9 ± 4.5	21.1 ± 6.0	0.450
Maximal oxygen uptake (ml/kg/min)	35.0 ± 7.4	38.8 ± 10.8	36.0 ± 9.9	34.0 ± 8.2	36.0 ± 9.1	0.581
Maximal power (W)	176.9 ± 25.9	173.9 ± 25.9	169.2 ± 41.0	171.1 ± 47.7	172.5 ± 35.7	0.958
Maximal heart rate (bpm)	171.4 ± 12.8*	185.0 ± 11.0	186.4 ± 11.3	185.6 ± 8.9	182.1 ± 12.4	0.003

Data are expressed as mean ± standard deviation (SD). BMI = body mass index. *p*-Value derived from one-way analysis of variance (ANOVA) for normally distributed data. *p* < 0.05 was considered statistically significant.

* Significantly lower than other groups.

can exceed ±10 bpm and prediction errors of up to 30 bpm in some cases (Tanaka et al., 2001). Therefore, all exercise intensities were prescribed using the HRmax values obtained directly from the test, which is considered the most accurate method for determining individualized training zones (ATS, 2002).

2.4.2. Emotional stimuli

Participants viewed 69 images from the IAPS, which had been previously validated and standardized (Bradley & Lang, 2017; Costa et al., 2022). The total presentation time was 30 min, adapted from Costa et al. (2022). Aversive images included distressing scenes such as accidents, physical threats, and aggressive confrontations, and were presented to participants allocated to the Aversive Control and Aversive Exercise groups. Neutral images, presented to participants in the Neutral Control and Neutral Exercise groups, were emotionally bland and included scenes such as wooden stools, suitcases lined up on the floor, a decorative ceramic plate on a table, and a person crocheting.

Based on normative IAPS ratings (Bradley & Lang, 2017), the aversive images used in the present study typically present low valence (≈ 2.2 – 2.8) and high arousal (≈ 5.8 – 6.5), whereas neutral images show mid-range valence (≈ 4.9 – 5.5) and low arousal (≈ 2.2 – 3.1). These values are consistent with those reported in recent Brazilian samples (Costa et al., 2022). Images were selected to ensure consistent emotional load and thematic coherence within each condition.

Images were displayed for 26 s each via PowerPoint presentation on a 42" monitor (Philips, 42PFL3507D/78, Brazil), positioned two meters from the participants.

2.4.3. State and trait anxiety symptoms assessment

State anxiety was assessed using the State Anxiety Inventory (STAI-S), following standard scoring procedures, where higher scores indicate higher state anxiety (Biaggio et al., 1977; Biaggio & Natalício, 1979). State anxiety reflects transient emotional responses to situational demands, whereas trait anxiety represents a relatively stable predisposition to perceive situations as threatening (Biaggio et al., 1977; Biaggio & Natalício, 1979). In this study, trait anxiety was assessed at baseline (Visit 1), while state anxiety was assessed at four time points: pre-intervention, immediately post-intervention, 10 min post, and 20 min post.

2.4.4. State and trait anger

Anger was measured using the State-Trait Anger Expression Inventory (STAXI), administered according to standard scoring procedures, with higher scores reflecting greater state anger. The instrument was translated and validated for Brazilian Portuguese (Spielberger et al., 1983; Spielberger & Biaggio, 1992). In the present protocol, trait anger was assessed during the first visit (baseline), whereas state anger was

measured at four time points: pre-intervention, immediately post-intervention, 10 min post, and 20 min post.

2.5. Statistical analysis

2.5.1. Sample size estimation

The sample size for this study was determined using the G*Power software (version 3.1, University of Kiel, Germany) (Faul et al., 2007). A repeated-measures analysis of variance with a between-within design was applied for the calculation. The effect size was estimated from preliminary data collected in the current study (16 participants).

For the outcome state anxiety, the partial eta squared (η^2_p) was 0.169, which was converted to Cohen's *f*, yielding a value of 0.451 for the interaction between group and time. The calculation was based on the following parameters: an alpha level (α) of 0.05, statistical power ($1 - \beta$) of 0.95, four independent groups, four repeated measures, and a correlation of 0.5 among repeated measures. The priori power analysis indicated a required sample size of 20 participants, with 5 participants per experimental group. For the outcome state anger, η^2_p was 0.252, corresponding to a Cohen's *f* of 0.580 for the interaction between group and time. The same parameters used for state anxiety were applied, resulting in a required sample size of 16 participants. To accommodate an anticipated dropout rate of 30%, the final sample size was set at 28, based on the highest required estimate (state anxiety).

2.5.2. Statistical methods

The protective effect of moderate physical exercise on symptoms of state anxiety and state anger was tested using a linear mixed model fit by a maximum likelihood estimate. We used the lmer R package (Bates et al., 2015) for model estimation. The number of identifications was included as a random effect on the intercept. The time (pre-session, post-session, post-10, and post-20) and session (neutral exercise, aversive exercise, neutral control, and aversive control) were included as fixed effects. The linear mixed model was modeled with a Gaussian distribution. The critical level of significance adopted was 0.05. All analyses were carried out using the R program version 4.3.3. We used the η^2_p as the effect size for the linear mixed model. The η^2_p was classified as trivial (< 0.01), small ($0.01 \leq \eta^2_p < 0.06$), medium ($0.06 \leq \eta^2_p < 0.14$), and large ($\eta^2_p \geq 0.14$) (Lakens, 2013).

Participant baseline characteristics were summarized using means and standard deviations and compared across groups using one-way analysis of variance (ANOVA). Data from emotional outcomes (state anxiety and state anger) are expressed as mean values with 95% confidence intervals. Estimated marginal means are presented.

P-values were adjusted using the Holm method, and degrees of freedom were estimated using the Kenward-Roger method. A *p*-value < 0.05 was considered statistically significant. To further examine

between-group differences, delta change analyses (e.g., post minus pre values) were conducted to assess the magnitude of variation across conditions.

3. Results

Table 1 presents the demographic and baseline characteristics of the participants across the four experimental groups. There were no statistically significant differences between groups in age, body mass, height, body mass index, trait anxiety, trait anger, or $\text{VO}_{2\text{max}}$ ($p > 0.05$). However, a significant group difference was observed for HRmax ($F(3,48) = 5.35$; $p = 0.003$; $\eta^2p = 0.25$). Post hoc tests indicated that participants in the Neutral Control group had significantly lower HRmax values compared with those in the Aversive Control ($p = 0.020$), Aversive Exercise ($p = 0.013$), and Neutral Exercise ($p = 0.008$) groups, whereas no differences were observed among the latter three groups ($p > 0.99$).

The HR during the interventions was 85.3 ± 21.7 bpm, 88.9 ± 19.8 bpm, 131.3 ± 9.4 bpm, and 133.2 ± 6.0 bpm for the Neutral Control, Aversive Control, Neutral Exercise, and Aversive Exercise conditions, respectively. These values corresponded to $53.2 \pm 12.8\%$, $48.2 \pm 11.0\%$, $70.5 \pm 4.7\%$, and $71.8 \pm 2.5\%$ of HRmax, as determined by the cardiopulmonary exercise test.

The linear mixed-effects model revealed no main effect of group ($F[3, 48] = 1.704$, $p = 0.179$) and no significant time \times group interaction ($F[9, 144] = 1.667$, $p = 0.102$; $\eta^2p = 0.089$, medium effect). A significant main effect of time was observed for state anxiety ($F[3, 144] = 3.531$, $p = 0.017$; $\eta^2p = 0.089$). Post hoc pairwise comparisons indicated a significant increase immediately post-session compared with pre-session baseline ($p = 0.021$). No other pairwise differences between time points were significant (all $p > 0.05$) (Fig. 2, Tables 2 and 3).

The linear mixed-effects model revealed no main effect of group ($F[3, 48] = 2.446$, $p = 0.075$). However, there was a significant main effect of time ($F[3, 144] = 5.733$, $p < 0.001$) and a significant time \times group interaction ($F[9, 144] = 2.156$, $p = 0.028$). Post hoc pairwise comparisons for time indicated that state anger was significantly higher immediately post-session compared to pre-session ($p = 0.0001$) and to 20 min post-session ($p = 0.025$). No other comparisons were significant (all $p > 0.05$) (Fig. 3, Table 4).

Complete estimated marginal means for all time \times group combinations are provided in Supplementary Tables S1 (anger) and S2 (anxiety), including means, standard errors, and 95% confidence intervals.

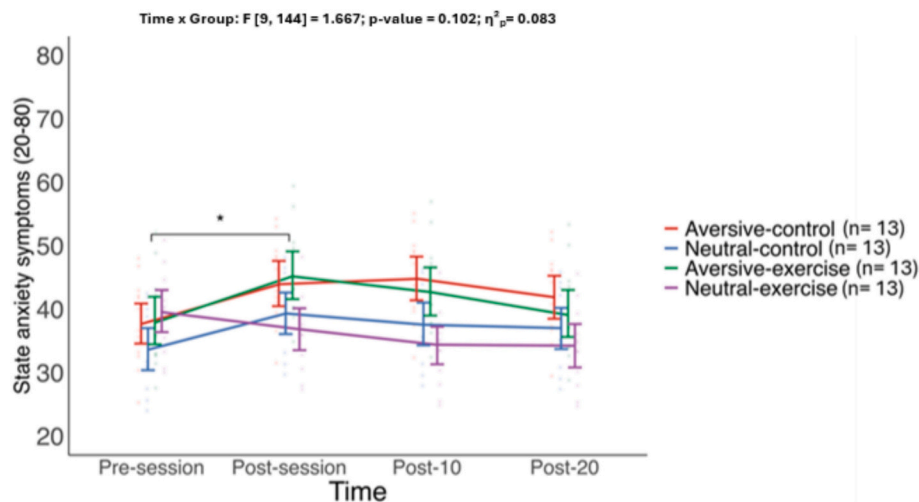


Fig. 2. State anxiety symptoms across measurements ($n = 52$).

Data are expressed as mean values with 95% confidence intervals. A significant main effect of time was observed ($p = 0.017$), with a medium effect size ($\eta^2p = 0.089$). A significant increase in state anxiety symptoms was found at the post-session time point compared to the pre-session baseline ($p < 0.05$), as indicated by the asterisk (*). Complete estimated marginal means for all conditions are provided in Supplementary Table S1.

Table 2

Linear mixed model results for state anxiety (STAI-S).

Effect	F	p -Value	η^2p
Time	3.531	0.017*	0.089
Group	1.704	0.179	0.045
Time \times group	1.667	0.102	0.083

Effects were tested using a linear mixed-effects model. Time represents repeated measurements (Pre, Post, Post-10, Post-20). Group represents experimental conditions. η^2p = partial eta squared. * $p < 0.05$ indicates statistical significance.

Table 3

Post hoc pairwise comparisons for state anxiety (main effect of time).

Comparison	Estimated mean difference	95% CI (lower, upper)	p -Value
Pre vs post-10	1.462	[-1.27; 4.19]	0.591
Post vs post-20	3.269	[0.54; 5.99]	0.101
Post vs pre	4.135	[1.40; 6.87]	0.021*
Post-10 vs post-20	1.808	[-0.91; 4.53]	0.589
Post-10 vs pre	2.673	[-0.04; 5.39]	0.227
Post-20 vs pre	0.865	[-1.87; 3.60]	0.591

Estimated marginal means are presented. CI = confidence interval. p -values were adjusted using the Holm correction. Degrees of freedom = 144 (Kenward-Roger method). *State anxiety symptoms were significantly higher at post-session compared to the pre-session baseline ($p < 0.05$).

Post hoc pairwise comparisons for the main effect of time (Table 5) indicated that state anger symptoms were significantly higher immediately post-session compared to pre-session ($p = 0.0001$) and also compared to 20 min post-session ($p = 0.025$). No other pairwise differences between time points reached statistical significance (all $p > 0.05$).

Post hoc analyses comparing within-group trajectories across adjacent time points (Table 6) revealed no statistically significant differences after applying Holm correction.

To further explore between-group differences, delta change analyses for state anger were performed (Table 7). A significant difference was observed between the neutral exercise and aversive exercise groups for the post-pre comparison ($p = 0.026$), in which participants in the neutral exercise group presented a lower state anger post intervention than those in the aversive exercise group pre intervention. All other

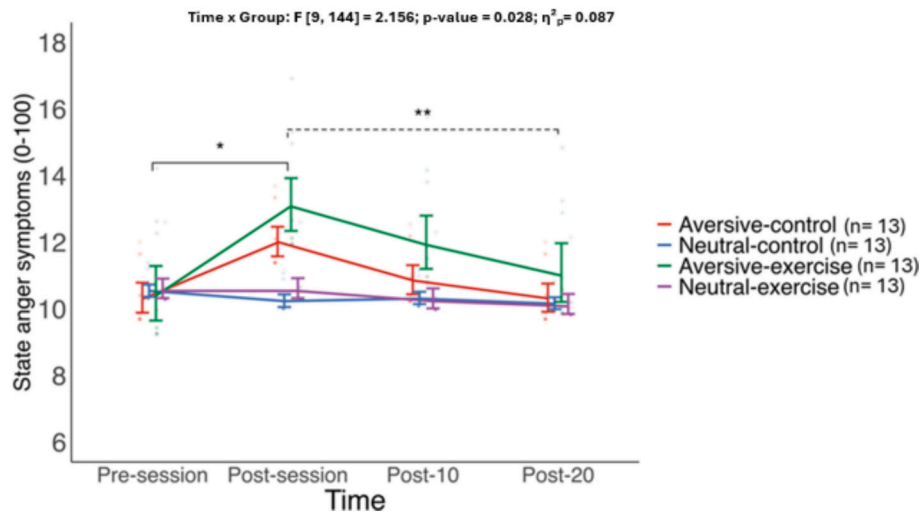


Fig. 3. State anger symptoms across time points (n = 52).

Data are presented as mean values with 95% confidence intervals. A significant time × session interaction was found ($F[9, 144] = 2.156; p = 0.028$), with a medium effect size ($\eta^2p = 0.109$). Complete estimated marginal means for all conditions are provided in Supplementary Table S2.

*State anger symptoms were significantly higher at post-session compared to the pre-session baseline ($p < 0.05$). **Post-session values were significantly higher than those at post-20 min ($p < 0.01$).

Table 4
Linear mixed model results for state anger (STAXI-S).

Effect	F	p-Value	η^2p
Time	5.73	<0.001*	0.109
Group	2.44	0.075	0.061
Time × group	2.15	0.028*	0.087

Effects were tested using a linear mixed-effects model. Time represents repeated measurements (Pre, Post, Post-10, Post-20). Group represents experimental conditions. η^2p = partial eta squared. * $p < 0.05$ indicates statistical significance.

Table 5
Post hoc pairwise comparisons for state anger (main effect of time).

Comparison	Estimated mean difference	95% CI (lower, upper)	p-Value
Post vs. pre	-2.692	[-4.10; -1.28]	0.0001*
Post vs. post-10	-1.154	[-2.87; 0.56]	0.927
Post vs. post-20	-2.077	[-3.85; -0.31]	0.025**
Post-10 vs. pre	-1.538	[-3.30; 0.22]	0.084
Post-20 vs. pre	-0.615	[-2.25; 1.02]	0.402
Post-10 vs. post-20	+0.923	[-0.64; 2.52]	0.318

Estimated marginal means are presented. CI = confidence interval. p-values were adjusted using the Holm correction. Degrees of freedom = 144 (Kenward-Roger method). *State anger symptoms were significantly higher at post-session compared to the pre-session baseline ($p < 0.05$). **State anger symptoms were significantly higher at post-session compared to the post-20 session ($p < 0.05$).

between-group comparisons of delta values did not reach statistical significance ($p > 0.05$).

4. Discussion

This study evaluated whether a single session of moderate-intensity continuous aerobic exercise, conducted under emotionally aversive conditions, would decrease symptoms of state anxiety and anger in young adult women. The primary findings indicated a significant main effect of time on both outcomes. However, exercise did not produce an anxiolytic effect, and although a significant time vs. group interaction was observed for anger, the exercise conditions did not demonstrate superiority over the control conditions (neutral or aversive) in

Table 6
Post hoc pairwise comparisons for state anger (interaction effects).

Comparison	Estimated mean difference	95% CI (lower, upper)	p-Value
Post aversive control vs. post-10 aversive control	1.154	[-0.47; 2.77]	0.927
Post neutral control vs. post-10 neutral control	-0.077	[-1.22; 1.06]	1.000
Post aversive exercise vs. post-10 aversive exercise	1.154	[-0.47; 2.77]	0.927
Post neutral exercise vs. post-10 neutral exercise	0.307	[-1.29; 1.90]	1.000
Post-20 aversive control vs. post-10 aversive control	1.154	[-0.47; 2.77]	0.927
Post-20 neutral control vs. post-10 neutral control	-0.077	[-1.22; 1.06]	1.000
Post-20 aversive exercise vs. post-10 aversive exercise	-0.923	[-2.55; 0.71]	1.000
Post-20 neutral exercise vs. post-10 neutral exercise	-0.154	[-1.75; 1.44]	1.000

Pairwise comparisons were derived from the linear mixed-effects model. CI = confidence interval. p-values were adjusted using the Holm correction.

modulating emotional responses. These results suggest that the potency of aversive visual stimuli may override the subtle regulatory benefits of acute exercise, supporting the “stimulus dominance” hypothesis.

Whereas most studies examining the anxiolytic or anger-reducing effects of exercise expose participants to stressors either before or after the physical activity (Ensari et al., 2015; Petruzzello et al., 1991; Rebar et al., 2015), fewer investigations have explored scenarios where emotional stress and physical exertion occur simultaneously (Hall et al., 2007; Petruzzello et al., 1991; Van Dis et al., 2020). This aspect is critical because simultaneous exposure may elicit competing psychophysiological responses.

Regarding state anxiety, the absence of a distinct exercise benefit likely reflects a “floor effect” (Andrade, 2021; Costa et al., 2022; Ekkekakis & Petruzzello, 1999; Ensari et al., 2015). Participants presented low baseline anxiety scores, leaving minimal margin for further reduction (Andrade, 2021; Ekkekakis & Petruzzello, 1999). Consequently, the significant time effect observed across all groups likely represents a natural decay of transient arousal rather than a specific intervention effect. Since our sample consisted of non-clinical young women with

Table 7

Pairwise comparisons of delta changes in state anger across experimental groups.

Comparison	Estimated mean difference	95% CI (lower, upper)	p-Value
Aversive exercise vs aversive control (post-pre)	-1.000	[-2.64; 0.64]	1.000
Neutral control vs aversive control (post-pre)	2.000	[0.36; 3.64]	0.315
Neutral exercise vs aversive exercise (post-pre)	2.692	[1.06; 4.33]	0.026*
Neutral exercise vs aversive exercise (post 10-post)	-0.846	[-2.48; 0.79]	1.000
Aversive control vs neutral control (post 10-post)	1.154	[-0.45; 2.76]	0.927
Aversive exercise vs aversive control (post 10-post)	1.154	[-0.45; 2.76]	0.927
Aversive exercise vs neutral exercise (post 10-post 20)	-0.385	[-2.19; 1.42]	1.000
Aversive control vs neutral control (post 10-post 20)	1.231	[-0.63; 3.09]	1.000
Aversive control vs aversive exercise (post 10-post 20)	2.077	[-0.31; 4.46]	0.255
Aversive exercise vs neutral exercise (post 20-post)	-1.615	[-3.62; 0.39]	0.927
Aversive control vs neutral control (post 20-post)	-1.615	[-3.62; 0.39]	0.927
Aversive control vs aversive exercise (post 20-post)	0.385	[-1.42; 2.19]	1.000

Pairwise comparisons were based on delta values. CI = confidence interval. p-values were adjusted using the Bonferroni correction. * $p < .05$ indicates statistical significance.

preserved emotional regulation, the aversive stimuli may have been insufficiently intense to trigger a magnitude of anxiety that would be responsive to the buffering effects of exercise. However, while the pattern observed aligns with previous findings, the mechanisms underlying this response in our sample remain hypothetical. Without physiological markers or neurocognitive measures, we cannot determine whether the observed effects reflect differences in attentional allocation, autonomic activation, or other regulatory processes.

In contrast, the persistence of anger in the Aversive Exercise group points to distinct psychophysiological mechanisms. Unlike anxiety, which is often linked to avoidance behaviors and withdrawal, anger is characterized by an approach-oriented motivational system and heightened sympathetic activation (Berkowitz & Harmon-Jones, 2004). Moderate-intensity exercise also acts as a physiological stressor, increasing sympathetic output. We hypothesize that rather than buffering the emotional response, the physiological arousal from exercise may have summated with the arousal induced by the aversive stimuli. This “arousal overlap” potentially fueled emotional inertia, the resistance to returning to baseline, mediated by shared neural substrates such as the amygdala and dorsal anterior cingulate cortex (Bertsch et al., 2020). Thus, the concurrent cognitive and metabolic demands may have depleted the requisite resources for effective downregulation of anger.

Our findings diverge from the “dual mode” or buffering hypotheses often observed when stress precedes exercise. Instead, they align with the concept of stimulus dominance, where the immediate salience of negative stimuli blunts the affective benefits of physical activity (Ensari et al., 2015). This is consistent with Costa et al. (2022), who observed heightened emotional reactivity in women exposed to aversive IAPS images. Conversely, discrepancies with studies showing anger increases in men (Thom et al., 2019) may be improved by methodological differences, specifically our use of the STAXI-S versus the more nuanced STAXI-2, and our exclusion of participants with elevated trait anger.

Prior work has proposed the concept of “stimulus dominance,” in which emotionally salient stimuli may override concurrent affective regulation (Andrade, 2021; Ekkekakis & Petruzzello, 1999; Ensari et al., 2015). Our results may be interpreted considering this hypothesis;

however, because our study did not include attentional or autonomic measures, this interpretation remains speculative (Andrade, 2021; da Silva et al., 2022). Despite the well-established benefits of exercise for emotional regulation (da Silva et al., 2022; Ensari et al., 2015), the concurrent presentation of aversive stimuli during exercise in the present study likely contributed to the attenuation of these effects.

For state anger, a significant time-by-group interaction was observed. Notably, post hoc analyses revealed that anger symptoms significantly increased in the aversive exercise group compared to baseline, while the neutral conditions remained stable. These findings suggest that when emotional arousal is elicited by aversive content, exercise may not buffer anger responses and might even sustain them due to cumulative physiological arousal (Perkins et al., 2001).

These findings should be interpreted considering that women typically show greater emotional reactivity to stressors and a higher prevalence of anxiety-related disorders (Domes et al., 2010; WHO, 2017) which may partly explain the sustained anger response observed under aversive exercise conditions. This interpretation is consistent with psychophysiological literature showing that anger is associated with high sympathetic activation and approach-oriented motivational systems (Berkowitz & Harmon-Jones, 2004; Harmon-Jones, 2003), as well as enhanced activation of neural circuits involving the amygdala and dorsal anterior cingulate cortex (Bertsch et al., 2020; De Gelder, 2006). Nevertheless, without direct physiological recording in our study, these links remain theoretical.

Our results partially align with Costa et al. (2022), who found that unpleasant images from the IAPS increased state anger in women but not in men, highlighting sex differences in emotional reactivity. However, unlike their design, which compared men and women in a passive viewing condition, our study included only women and examined their responses to aversive stimuli presented concurrently with aerobic exercise. Therefore, while both studies demonstrate that women may exhibit heightened anger responses to unpleasant stimuli, our findings suggest that such reactivity may persist even in the presence of an exercise-induced regulatory context.

4.1. Limitations and future directions

This study presents notable strengths, including a randomized controlled design, validated measures of emotional reactivity (STAI-S and STAXI-S), and robust statistical modeling. The simultaneous exposure to exercise and emotionally aversive stimuli enhances ecological validity, representing real-world situations in which individuals must perform under acute emotional load.

However, several limitations warrant consideration when interpreting these data. First, emotional states were measured using self-report instruments, which do not directly capture physiological stress responses and may be influenced by cognitive bias. Second, the absence of hormonal or autonomic biomarkers limits interpretation of the psychophysiological mechanisms underlying the findings. Third, although the date of last menstruation was recorded, menstrual cycle phase was not prospectively controlled nor hormonally verified. Therefore, cycle-related hormonal fluctuations could not be precisely accounted for and may have contributed to variability in emotional responses. Fourth, the sample consisted exclusively of young adult women, which limits generalizability. It is important to emphasize that all mechanistic interpretations proposed here should be viewed as hypotheses rather than confirmed causal pathways. Fifth, regarding statistical power, the study was designed to detect medium-to-large interaction effects. Sensitivity analyses indicated that the present sample size provided adequate power ($\geq 80\%$) to detect interaction effects of small-to-moderate magnitude ($\eta_p^2 \approx 0.04-0.05$), whereas very small effects ($\eta_p^2 \leq 0.02$) would not be reliably detectable. Therefore, the absence of a statistically significant interaction effect for state anxiety should not be interpreted as definitive evidence of no effect, but rather as an absence of statistical evidence for interaction effects of at least small-to-moderate magnitude.

Future studies should incorporate physiological biomarkers, explore repeated or chronic exercise exposures, and examine sex differences and hormonal influences more directly. Including diverse populations, such as men, older adults, and clinical groups, will broaden the applicability of these findings and clarify contextual moderators of exercise-induced emotion regulation.

5. Conclusion

This study provides evidence that performing a single session of moderate-intensity aerobic exercise concurrently with exposure to emotionally aversive stimuli does not attenuate acute symptoms of anxiety or anger in young women. In fact, anger responses persisted longer and were amplified in the aversive exercise condition. These findings highlight that emotional context can override the affective benefits typically attributed to exercise.

These results underscore the importance of emotional context in shaping the affective outcomes of exercise. Rather than serving as a buffer, moderate-intensity aerobic activity under emotional load may be insufficient, or even counterproductive, for regulating negative emotions, likely due to the additive demands of physical and psychological stress. In conclusion, a single bout of moderate-intensity exercise performed on an Air Bike under emotionally aversive conditions was insufficient to mitigate acute increases in anxiety and anger symptoms.

CRedit authorship contribution statement

Mila Alves Matos Rodrigues: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Vinnycius Nunes de Oliveira:** Conceptualization, Formal analysis, Methodology, Writing – review & editing. **Nicolas Evangelista Marques:** Data curation, Investigation, Writing – review & editing. **João Victor Rosa de Freitas:** Data curation, Investigation, Writing – review & editing. **Bráulio Evangelista de Lima:** Formal analysis, Methodology, Writing – review & editing. **Marília Santos Andrade:** Writing – review & editing. **Rodrigo Luiz Vancini:** Conceptualization, Writing – review & editing. **Katja Weiss:** Writing – review & editing. **Beat Knechtle:** Writing – review & editing, Conceptualization. **Ricardo Borges Viana:** Formal analysis, Methodology, Writing – review & editing. **Claudio Andre Barbosa de Lira:** Conceptualization, Project administration, Supervision, Writing – review & editing.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors declare that no generative artificial intelligence (AI) tools were used in the writing, data analysis, or preparation of this manuscript.

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Declaration of competing interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.actpsy.2026.106714>.

Data availability

Data will be made available on request.

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