Acta Psychologica 264 (2026) 106371

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Cardiorespiratory fitness is associated with lower anger and anxiety and higher emotional resilience

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ARTICLE INFO

Keywords:
Physical fitness
Irritable mood
Anger
Anxiety
Psychological resilience

ABSTRACT

Background and aims: Physical activity is part of the treatment for several mental diseases, including anxiety disorders. However, it is not known whether individuals with higher levels of physical fitness experience lower levels of anxiety or stressful emotions. It is also unknown whether those individuals can better control their emotions in stressful situations. The aim of this study was to examine whether high cardiorespiratory fitness is associated with lower trait levels of anger and anxiety, and whether individuals with different fitness levels show distinct emotional responses to unpleasant visual stimuli.

Methods: On separate days, 40 healthy young participants completed two sessions. Trait anxiety and anger were assessed during the first session to characterize the participants. The participants self-reported their exercise practice to predict cardiorespiratory fitness (CRF). The participants' anger/anxiety levels were assessed before and after exposure to a 69-picture set of unpleasant or neutral pictures for 30 min.

Results: Multiple regression analysis showed that maximal oxygen uptake (VO_2max) ($\beta = -0.241$, $t = -3.173$, 95% confidence interval CI [−0.395; −0.087], $p = 0.003$) and anger-out ($\beta = 0.333$, $t = 2.124$, 95%CI [0.015; 0.651], $p = 0.040$) were predictors of changes in anger-state in the unpleasant picture presentation. Individuals with a VO_2max below average (BA) had a 775% greater risk for changing their classification from intermediate to high anxiety levels compared to above average (AA) individuals (OR = 8.754, 95%CI [1.202; 63.759]). VO_2max was a predictor of trait anxiety ($\beta = -0.456$, $t = -3.485$, 95%CI [−0.721; −0.191]; $p = 0.001$).

Conclusion: CRF is associated with lower levels of trait anxiety and higher resilience in situations of emotional stress.

1. Introduction

Anger is a complex emotional response that may occur frequently and intensely in individuals with specific personality traits (Veenstra, Bushman, & Koole, 2018). Research has linked such persistent emotional reactivity with anxiety, particularly in stress-related disorders (de Bles et al., 2019). Anger attacks are more common among people diagnosed with anxiety disorder (Painuly, Grover, Gupta, & Mattoo, 2011). In the U.S., a study with 34,442 adults showed an overall 7.8% prevalence of intense anger, and 46% of those who reported high anger

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https://doi.org/10.1016/j.actpsy.2026.106371
Received 13 March 2025; Received in revised form 22 January 2026; Accepted 27 January 2026
Available online 6 February 2026

symptoms also reported higher anxiety symptoms (Okuda et al., 2015). The high prevalence of these disorders is worrying because they are associated with cardiovascular, respiratory, and neuroendocrine diseases (Chida & Steptoe, 2009; Lamers et al., 2019; Suls, 2013; Zainal & Newman, 2021); poor quality of life (Kahnert, Kämpfer, Ramm, Geiser, & Conrad, 2025); poor quality of sleep (Mayers, Grabau, Campbell, & Baldwin, 2009; Van Veen, Lancel, Beijer, Remmelzwaal, & Rutters, 2021); and higher risk for suicide (Ferrari et al., 2014). Therefore, this condition arises at a high cost to public health (Newman, Llera, Erickson, Przeworski, & Castonguay, 2013). For example, in Europe in 2010, 74.4 billion euros were expended to manage anxiety disorders (Gustavsson et al., 2011). Globally, the total cost of all mental illnesses is projected to reach US$ 6.0 trillion by 2030 (Bloom et al., 2011). Furthermore, estimates of annual direct and indirect costs per patient for various brain disorders in Europe indicate that anxiety disorders cost approximately US$ 3874 per patient per year (Li & Jönsson, 2025).

The literature that shows that high anxiety levels are associated with high sedentary behavior is also of interest to the present study (Vancampfort, Stubbs, Herring, Hallgren, & Koyanagi, 2018). On its own, high sedentary behavior is already associated with non-communicable diseases (Addoh, Edwards, & Loprinzi, 2016; Dvorak et al., 2000; Hillreiner et al., 2020; Imboden et al., 2018; Kodama, 2009). For this reason, further studies investigating strategies to manage anxiety and its consequences, such as anger, are needed. It will also be of great interest to learn whether physically fit people can respond better to stressful situations and better emotionally.

Sedentary behavior is consistently associated with lower cardiorespiratory fitness (CRF). Lower CRF, in turn, has been linked to a higher risk of cardiovascular disease (Addoh et al., 2016; Kodama, 2009), cancer (Hillreiner et al., 2020; Imboden et al., 2018), and poorer mental health (Becofsky et al., 2015; Xu, Ji, & Wen, 2025). Importantly, the relationship between sedentary behavior and anxiety appears to be bidirectional: higher anxiety levels can lead individuals to engage in less physical activity, while prolonged sedentary behavior may also contribute to increased anxiety symptoms. Evidence from previous studies shows that regular physical activity can reduce both anxiety (Kandola et al., 2018) and stress (Pedersen & Saltin, 2015), reinforcing the idea that enhancing CRF may play a protective role in emotional well-being. Regular physical activity can also protect against acute stress (Childs & de Wit, 2014). Furthermore, a single acute session of aerobic exercise can decrease anxiety symptoms (Morais et al., 2021; Viana et al., 2017) and protect against rising anxiety symptoms (Smith, 2013) and anger levels (Thom, O'Connor, Clementz, & Dishman, 2019) arising due to emotional exposure.

Alternatively, physical activity interventions have been shown to effectively reduce symptoms of anxiety and psychological distress. An overview of systematic reviews by Singh et al. (2023) reported that physical activity programs, including aerobic training capable of significantly improving cardiorespiratory fitness (CRF), benefit a wide range of populations, from healthy adults to individuals with mental health disorders and chronic diseases. Moreover, regular physical activity has been shown to enhance quality of life, particularly in people with depression (Noetel et al., 2024), and to improve cognitive function in individuals with schizophrenia (Shimada et al., 2022). Notably, these groups are also known to present higher levels of anxiety symptoms.

Nevertheless, exercise interventions that enhance CRF can improve anxiety symptoms through a plethora of mechanisms that are not completely clear in the current literature, but some examples are the regulation of stress responses through the hypothalamic-pituitary-adrenal axis and glucocorticoid circulation (Anderson & Shivakumar, 2013), enhancing neurogenic processes crucial for brain functioning, such as increasing levels of growth factors like brain-derived neurotrophic factor and stimulating neurogenesis, angiogenesis, and hippocampal functioning (Kandola, Hendrikse, Lucassen, & Yücel, 2016).

Growing evidence suggests that the beneficial effects of cardiorespiratory fitness (CRF) on mental health outcomes are not merely direct but are partly mediated by resilience-related mechanisms (Pozuelo-Carrascosa et al., 2017). Specifically, higher levels of CRF appear to enhance emotional resilience, which in turn contributes to better mental components of health-related quality of life. This relationship may be explained by the protective role of physical activity and fitness against stress and stress-related disorders, promoting more adaptive emotional responses to challenging situations (Salmio et al., 2024). Within this framework, one can postulate that emotional resilience may manifest as a greater capacity to regulate stress-related emotions such as anxiety and anger, thereby reducing maladaptive affective reactivity under adverse conditions.

Modern lifestyles are associated with exposure to emotional stress through traffic, family, work, financial problems, and urban violence, and this stress can harm general health (Chida & Hamer, 2008; Kim, Choi, & Kim, 2022). Stressful life events can decrease the practice of physical activity and, consequently, of CRF (Paluch et al., 2018). Understanding how these emotional states interact with physiological resilience, especially as influenced by physical fitness, is essential. This study focuses on how variations in cardiorespiratory fitness (CRF) relate to anger and anxiety modulation in response to emotionally charged visual stimuli. Our primary hypothesis is that participants with higher CRF would be more resilient to anger/anxiety changes derived from emotional picture stimuli than those with lower CRF. Moreover, trait anger and trait anxiety will be lower in those with higher CRF.

2. Methods

In all, 40 healthy participants (23 women and 17 men) were recruited through personal invitations and advertisements on social media. The inclusion criterion was age between 18 and 40 years. The exclusion criteria were (1) a clinical diagnosis of anxiety or other mental disorders and (2) the use of psychoactive medications. All participants were informed of the procedures, and informed consent was obtained before data collection. All procedures were approved by the University Research Ethics Committee (approval number: 28896019.1.0000.5083) and were performed following the principles outlined in the latest version of the Declaration of Helsinki in 2013. The participants' characteristics are shown in Table 1.

2.1. Study design

A within-subjects experimental design was used in this study. All the participants visited the laboratory twice. All sessions were separated by 24–72 h. Participants attended the laboratory on two occasions separated by 24–72 h. During the first visit, anthropometric measures, trait anxiety (Spielberger, Gorsuch, & Lushene, 1970), and trait anger (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) were assessed to characterize the sample. CRF (maximal oxygen uptake - VO_2max) was estimated from self-reported physical activity using a validated non-exercise equation (Jackson et al., 1990), and participants were classified into above average (AA; $n = 26$) or below average (BA; $n = 14$) fitness group based on Brazilian references values (Rossi Neto et al., 2019). Participants also received instructions about the experimental procedures and were familiarized with the emotional pictures selected from the International Affective Picture System (IAPS), a validated repository of emotionally graded images (Smith, Bradley, & Lang, 2005). This system includes both neutral and unpleasant images, the latter often associated with physiological and emotional responses such as increased arousal, anxiety, and anger. The images are commonly used to examine affective processing in experimental settings focused on emotional regulation (Costa et al., 2022; Smith, 2013; Smith et al., 2005; Thom et al., 2019; Viana et al., 2021). The pictures used in current study were selected by two researchers (R.B.V. and C.A.B.L.).

Participants were exposed to two 69-picture sets, one of unpleasant and other of neutral pictures, for 30 min, each visit they visualized one of the sets, the order of the type of 69-picture sets (neutral or unpleasant)

Table 1
Participant characteristics (n = 40).

	All (n = 40)	VO_2max AA (n = 26)	VO_2max BA (n = 14)	p-value	Effect size	Effect size classifications
Men / Women#	–	15/11	2 / 12	0.008	0.419	Relatively strong association
Age (years)	20.5 [6.5]	20.5 [4.5]	20.5 [10]	0.566	0.409	Intermediate
Body mass (kg)	68.6 [19.3]	70 [21]	67 [11]	0.878	0.273	Small
Height (m)	1.65 [0.1]	1.70 [0.1] *	1.61 [0.1]	0.013	0.715	Large
BMI (kg/m^2)	24.6 ± 4.6	23.4 ± 3.2*	26.9 ± 5.9	0.018	0.819	Large
VO_2max (ml.kg^{-1}.min^{-1})	42.2 ± 8.7	47.1 ± 5.7*	33.2 ± 5.4	< 0.001	2.478	Large
Trait anxiety	41 ± 9	38 ± 7*	44 ± 11	0.048	0.677	Intermediate
Trait anger	19 [6]	18 [5]	20 [6]	0.237	0.325	Intermediate
Angry temperament	6 [3]	6 [2]	9 [6]	0.066	0.684	Large
Angry reaction	8 [3]	8 [3]	8 [3]	0.851	0.062	No effect
Anger-in	18 ± 4	19 ± 5	21 ± 5	0.265	0.375	Small
Anger-out	15 ± 4	15 ± 4	16 ± 4	0.593	0.179	Small
Anger-Control	22 ± 5	23 ± 5*	18 ± 5	0.009	0.918	Large
Anger-Expression	29 ± 9	26 ± 8*	32 ± 8	0.045	0.751	Large

Data are reported as means ± standard deviations and median [Interquartile Range]. BMI: body mass index; kg: kilograms; m: meters; min: minutes. VO_2max: maximal oxygen uptake. * Significant difference between the samples assessed by an independent t-test and the Mann-Whitney test ($p < 0.05$), effect size, respectively, Cohen's d or Rank-biserial correlation; # significant difference between the samples at chi-squared analysis ($p < 0.05$), effect size φ (phi-coefficient); AA: Above average; BA: below average.

was randomized using a drawing; 23 individuals (13 women and 10 men) began with the unpleasant set, and 17 (10 women and 7 men) began with the neutral set. After the initial characterization on the first visit, the participants visualized one picture set (neutral or unpleasant).

Emotional responses to the images were assessed using the Self-Assessment Manikin (SAM), a validated non-verbal scale that captures valence, arousal, and dominance dimensions (Lang, Bradley, & Cuthbert, 2008a). State anxiety and anger were assessed immediately before and after each picture set.

Extraneous conversation was minimized during all parts of the data collection, and, apart from the participants, only the researchers in the study were allowed in the room. Heart rates were assessed during picture viewing. All sessions were conducted at the same time of day for each participant to minimize circadian influences.

All the participants were instructed to abstain from caffeine, alcohol, and physical activity for 24 h before the experiment and to eat a light meal before the intervention. The laboratory temperature was adjusted from 21 °C to 23 °C, and the lights were turned off to better enable picture visualization (Costa et al., 2022).

No medical complications occurred during the experimental procedures. All experimental procedures were completed within 1 week.

2.2. Experimental procedures

2.2.1. Emotional states assessment

To assess participants' emotional states, we used validated instruments adapted for the Brazilian population. The State-Trait Anger Expression (STAXI) was employed to measure anger tendencies and expressions across both situational and dispositional dimensions (Spielberger & Biaggio, 1992; Spielberger, Jacobs, Russell, & Crane, 1983). Similarly, the State-Trait Anxiety Inventory (STAI) provided a standardized evaluation of state and trait anxiety, distinguishing between momentary emotional responses and general predispositions to anxiety, respectively (Gorenstein & Andrade, 1996; Spielberger et al., 1970). STAXI was used to assess both transient and habitual anger expressions. The instrument provides separate scores for state and trait anger and includes additional subscales that reflect anger expression and control tendencies. State anger was assessed using 10 items and a 4-point intensity scale: 1) Not at all, 2) Somewhat, 3) Moderately, and 4) Very much. Trait anger, evaluating how participants generally felt by asking them how they felt "in general," was assessed using 10 items and a 4-point intensity scale: 1) Almost never, 2) Sometimes, 3) Frequently, and 4) Almost always. The other scales were angry temperament (four items from the trait scale), angry reaction (four items from the trait scale), anger-in (eight items), anger-out (eight items), anger control (eight items), and anger expression (anger-in + anger-out − anger-control).

The STAI was employed to measure temporary (state) and dispositional (trait) anxiety. Each dimension was assessed through a standardized set of items validated for the Brazilian population. Scores were categorized into low (≤30), intermediate (31–49), or high (≥50) levels of anxiety according to established cut-off points (Julian, 2011; Knight, Waal-Manning, & Spears, 1983), and classification changes were monitored before and after emotional exposure, the temporary state was assessed using 20 items and a 4-point intensity scale: 1) Not at all, 2) Somewhat, 3) Moderately, and 4) Very much. The second scale, used to evaluate the trait anxiety, was used to evaluate trait aspects of anxiety by asking how the participants felt "in general," using 20 items and a 4-point intensity scale: 1) Almost never, 2) Sometimes, 3) Often, and 4) Almost always.

2.2.2. IAPS and SAM

The IAPS has been widely used as visual stimulus set to elicit emotional responses such as anger and anxiety (Smith, 2013; Smith et al., 2005; Thom et al., 2019), including in studies conducted with Brazilian samples (Costa et al., 2022; Lasaitis, Ribeiro, & Bueno, 2008; Silva et al., 2025; Morais et al., 2025; Viana et al., 2021). For each session, a standardized slideshow was programmed. Participants first viewed instructional slides and then a sequence of IAPS images, each displayed for 6 s. All information regarding image exposure and SAM instructions was presented using Microsoft PowerPoint (Microsoft Office Professional Plus, 2016, USA). During the session, participants remained seated in a chair positioned two meters from a television screen (Philips, 42PFL3507D/78, Brazil).

After each image, a rating screen prompted the participant to assess the emotional content using the SAM. This non-verbal instrument captures subjective emotional responses across three dimensions, valence, arousal, and dominance, on a 9-point scale. Participants had 15 s to complete each rating using a paper-based form. Three neutral images from public sources were shown as examples for familiarization with the rating procedure. The entire session lasted approximately 30 min, consistent with established protocols (Costa et al., 2022; Lang, Bradley, & Cuthbert, 2008b; Smith, 2013; Thom et al., 2019). Participants were instructed to remain silent and attend fully to each image during its display. The specific image sets used in the unpleasant and neutral conditions are detailed in the supplementary material.

2.2.3. Cardiorespiratory fitness assessment

To estimate cardiorespiratory fitness, we used a VO_2max prediction model that does not involve exercise testing (N-Ex), as used by Jackson et al. (1990). This equation uses self-reported physical exercise (PA-R, scale range from 0 to 7, regarding weekly exercise frequency and intensity) in combination with age, body mass index (BMI), and sex. The equation was $VO_2max = 56.363 + 1.921(PA\text{-}R)–0.381(age)–0.754(BMI) + 10.987$ (sex, 0 for women and 1 for men).

This equation was reliable for cross-validation with VO_2max measured using expired gases analysis during the Bruce treadmill protocol (Bruce, Kusumi, & Hosmer, 1973), with a correlation coefficient of 0.79 in a normal healthy sample. The coefficient of determination for the equation was 0.62, with a standard error of 5.7 $ml.kg^{-1}.min^{-1}$. After calculating the of VO_2max, we classified the sample into two groups according to this value: AA; $n = 26$) or BA; $n = 14$), according to reference values for the Brazilian population (Rossi Neto et al., 2019) (Table 1).

2.2.4. Heart rate assessment

Heart rate was monitored using a heart rate monitor (model V800, Polar, Finland), attached at the height of the xiphoid process of the participants. Following the session, the data were downloaded to a computer.

2.3. Statistical analysis

We confirmed the efficacy of the emotional stimuli by comparing responses in the outcome measures (anger and anxiety) between the two sessions, using single-factor (session [neutral x unpleasant]) and repeated measures analysis of variance (ANOVA), with partial eta-squared (η^2_p) as effect size measure (Espírito-Santo & Daniel, 2018), Bonferroni's post hoc was used when necessary. A priory analysis was made using effect size for the three way interaction (sex x session x time, $F = 9.092$; $p = 0.005$; $\eta^2p = 0.193$), using G*power (version 3.1.9.7, University of Dusseldorf), we converted η^2p (0.183) to f effect size, resulting in 0.489, based on that, we would need a sample size of 24 to reliably (with probability greater than 0.95) detect a statistical difference, assuming a two-sided criterion for detection that allows for a maximum type I error rate of $\alpha = 0.05$. Posteriori analysis using anger repeated measures ANOVA with between-subjects factor (above × below VO_2max) effect size results ($\eta^2p = 0.191$), showed that a design with a sample size of 36 sample can detect variance with a probability of 0.99, assuming a two-sided criterion for detection that allows for a maximum type I error rate of $\alpha = 0.05$.

The data were analyzed using the JASP (version 0.12.2, University of Amsterdam, Netherlands). The Shapiro–Wilk normality analysis detected non-normality for trait anger, angry temperament, angry reaction, height, BMI, and age. Data are presented as means ± standard deviations (for normality data) and medians [quartile intervals] (non-normality data). Mean differences (Δ) from the unpleasant sessions (pre-post) were expressed in absolute and relative (%) values. An independent samples *t*-test or Mann-Whitney was used to compare information on the two groups (above × BA on VO_2max), and chi-squared analysis for categorical variables (women × men), as well as baseline measures for anger, anxiety, and heart rate. The Cohen's d effect size was the choice for t-test, with the following classification: “no effect” ($d < 0.10$), “small” ($0.10 \leq d < 0.40$), “intermediate” ($0.40 \leq d < 0.70$), and “large” ($d \geq 0.7$) (Lenhard & Lenhard, 2016). The rank-biserial correlation (r_b) was the choice for Mann-Whitney, with the following classification: no effect” ($r_b < 0.10$), “small” ($0.10 \leq r_b < 0.30$), “intermediate” ($0.30 \leq r_b < 0.50$), and “large” ($r_b \geq 0.5$) (Lenhard & Lenhard, 2016). For Qui-squared we choose effect size φ (phi-coefficient), with the following classification: “Negligible association” ($\varphi < 0.10$), “weak association” ($0.10 \leq \varphi < 0.20$), “moderate association” ($0.20 \leq \varphi < 0.40$), “relatively strong association” ($0.40 \leq \varphi < 0.60$), and “strong association” ($\varphi > 0.60$) (Rea & Parker, 1992).

A one-factor (time on unpleasant session [pre x post]) repeated measure ANOVA with between-subjects factor (above x below VO_2max) was used to determine where there is a difference between the two groups in terms of anxiety and anger levels, comparing pre x post-anger/anxiety levels on unpleasant session between the two groups.

Multiple regression analysis (Schneider, Hommel, & Blettner, 2010) was used to assess the possible association between trait anger and anxiety, as well as the Δ of anger and anxiety for an unpleasant session with VO_2max. A logistic regression was utilized to verify the possible association between the change in anxiety classification after an unpleasant session (low to intermediate, intermediate to high, and low to high) (Spielberger, 1989) with the classification of VO_2max (AA or BA), following Rossi Neto et al. (2019). The Mcfadden R^2 was utilized to evaluate the model adjustment, with a suggested range from 0.2 to 0.4, indicating a good fit to the model (Goss-Sampson, 2024).

Because the sample was small relative to the number of variables, adjusted R^2 was used to quantify the proportion of variance explained by the model using the predictors provided (Austin & Steyerberg, 2015). Adjusted R^2 was classified following Ferguson (2009), from small ($0.04 \leq$ adjusted $R^2 < 0.25$) to moderate ($0.25 \leq$ Adjusted $R^2 < 0.64$) and strong (adjusted $R^2 \geq 0.64$). Because the variance inflation factor (VIF) was lower than 10, and the tolerance was higher than 0.1, we assume that the assumptions for regression analysis were not violated. The residuals vs. the predicted plots showed a pattern of homoscedasticity, and the Q–Q plot shows that the standardized residuals fit along with the diagonal line, suggesting the normality and linearity of the models. In addition, case-wise diagnostics showed no cases of residuals that were 3 or more standard deviations away from the mean (Goss-Sampson, 2024).

3. Results

For positive control of the method used in this study (i.e., an increase of state anger and state anxiety due to exposure to unpleasant pictures), ANOVA was performed and showed a significant effect of the session (anxiety: $F(3, 117) = 48.133$, $p < 0.001$, $\eta^2_p = 0.552$; anger: $F = 32.613$, $p < 0.001$, $\eta^2_p = 0.455$). Post hoc Bonferroni correction showed that the state anxiety level was higher after the unpleasant session (Δ: 12 [95% CI: 9; 16], $p < 0.001$) relative to the pre-unpleasant session, and there was no significant difference post-neutral session ($p = 1.000$). Bonferroni's post hoc also showed that the level of state anger was higher post-unpleasant session (Δ: 5 [95%CI: 3; 6], $p < 0.001$) compared to the pre-unpleasant session. Again, there were no significant differences in the neutral session ($p = 1.000$).

There were no significant differences in the baseline between groups related to trait anger, trait anxiety, and HR (Table 2).

One-factor (time in unpleasant session [pre × post]) repeated measures ANOVA with between-subjects factor (above × below VO_2max) was used to confirm whether there was a difference between the two groups on anxiety and anger levels, comparing pre x post-anger/anxiety levels on unpleasant session in the two groups. For anxiety, the test showed effects of time ($F(1,38) = 56.394$, $p < 0.001$, $\eta^2_p = 0.597$), session ($F(1, 38) = 55.079$, $p < 0.001$, $\eta^2_p = 0.592$), and between subjects ($F(1,38) = 5.349$, $p = 0.026$, $\eta^2_p = 0.123$), interaction between time and

Table 2
The baseline values of psychological measures and mean heart rates among unpleasant sessions ($n = 40$).

	AA (n = 26)	BA (n = 14)	Cohen's d [95% CI]	Cohen's d classification
State anger	10 ± 1	10 ± 1	0.329 [−0.327; 0.981]	Small
State anxiety	33 ± 6	36 ± 7	0.514 [0.149; 1.171]	Intermediate
Heart rate (bpm)	80 ± 11	85 ± 9	0.441 [−0.219; 1.095]	Intermediate

Data are presented as means ± standard deviations. AA: Above average; BA: below average, according to Rossi Neto et al. (2019) classification of VO_2max from the Brazilian population.

subjects (F (1, 38) = 5.637, $p = 0.023$, $\eta_p^2 = 0.129$), session and subjects (F (1, 38) = 7.395, $p = 0.010$, $\eta_p^2 = 0.163$), but no interaction session x time x subjects ($p = 0.055$). For anger, we found the respective results, effects of time (F = 44.797, $p < 0.001$, $\eta_p^2 = 0.541$), session (F (1, 38) = 35.166, $p < 0.001$, $\eta_p^2 = 0.481$) and between subjects (F = 5.219, $p = 0.028$, $\eta_p^2 = 0.121$), interaction of time and subjects (F (1, 38) = 9.105, $p = 0.005$, $\eta_p^2 = 0.193$), session and time (F (1, 38) = 55.096, $p < 0.001$, $\eta_p^2 = 0.592$), and between time x session and subjects (F (1, 38) = 8.943, p = 0.005, c). Bonferroni's post hoc showed higher anxiety-anger post-unpleasant session on BA individuals, compared with AA (anxiety: Δ: 10 [95%CI: 4; 17], p < 0.001; anger: Δ: 4 [95%CI: 1, 6], $p = 0.003$), and no significant difference was seen for baseline values (anxiety: p = 1.000; anger: p = 1.000) (Fig. 1).

Multiple linear regression models were fitted to examine the associations between trait anger, anger-in, anger-out, and VO_2max with changes in anger (Δ anger) during the unpleasant picture session. The variables that were better adjusted to the model [F(2, 37) = 7.525, $p = 0.002$, R^2 adjusted = 0.251) were VO_2max (β = −0.241, $t = -3.173$; 95%CI [−0.395; −0.087], p = 0.003) and anger-out (β = 0.333, $t = 2.124$, 95%CI [0.015; 0.651]; $p = 0.040$). Multiple regression analysis to predict Δ anxiety in the unpleasant session association by trait anxiety and VO_2max did not have statistical significance ($p = 0.208$). Nevertheless, for state anxiety, we utilized the classification of Spielberger (1989) as low (≤30), intermediate (31 to 49), and high (≥50) state anxiety and categorized the changes in classification between pre- and post-unpleasant session, as follows: 17 individuals remained in the same category (intermediate), 12 passed from low to intermediate, and 10 passed from intermediate to high. The logistic regression to verify the possible association between change of anxiety classification after an unpleasant session (low to intermediate, intermediate to high, and low to high) with classification of VO_2max (AA or BA), showed a significant statistical model ($X^2(35) = 11.762$, $p = 0.019$, R^2 McFadden = 0.227), such that individuals with VO_2max BA had a 775% greater risk to change their classification from intermediate to high compare to AA individuals (OR = 8.754, 95%CI = 1.202; 63.759).

The multiple regression to analyze the prediction of VO_2max and trait anxiety, with trait anger as a covariable, showed a statistically significant model [F(2, 37) = 14.252, p < 0.001, adjusted R^2 = 0.405), with VO_2max as trait anxiety predictor (β = −0.456; $t = -3.485$, 95%CI [−0.721; −0.191]; $p = 0.001$), as well as the trait anger (β = 0.691, $t = 3.230$, 95%CI[0.258; 1.124]; p = 0.003). Trait anger was also made a dependent variable, and the model was statistically significant [F(2, 37) = 6.293, $p = 004$, R^2 adjusted = 0.213), although only trait anxiety was a predictor of trait anger (β = 0.318, t = 3.230, 95%CI [0.119; 0.518], p = 0.003).

The multiple regression models that were fitted are presented in Table 3.

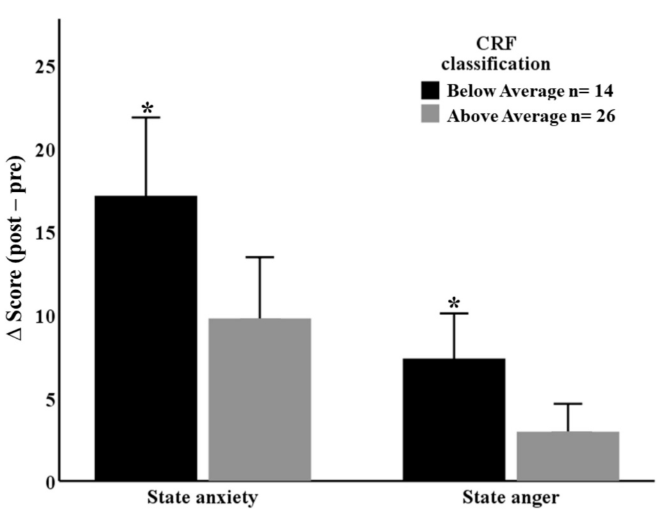

Fig. 1. Difference between the classifications of cardiorespiratory fitness (CRF) in state changes in anxiety-anger (pre-post) with unpleasant picture viewing. Difference between below and above average VO_2max classification of in Δ score (pre-post) at the unpleasant session. * Significantly higher than above average for the specific state (anxiety or anger).

4. Discussion

This study investigated the association between CRF and trait anxiety-anger and anger/anxiety-induced changes following IAPS emotional picture stimuli. Our main results were that the exposure to unpleasant pictures evoked an increase in state anxiety and state anger, and this increase was higher in participants with lower VO_2max. Furthermore, higher VO_2max was associated with lower trait anger and anxiety.

Multiple studies have shown that regular physical exercise is useful for preventing and treating psychiatric symptoms (Childs & de Wit, 2014; Mücke, Ludyga, Colledge, & Gerber, 2018; White et al., 2017). Along the same lines, our results show that participants with lower VO_2max values present higher state anxiety (44 ± 11) than those with higher VO_2max (38 ± 7, $p = 0.048$). This has been found previously in epidemiological data showing that physically active people tend to have lower anxiety levels and be less likely to suffer from anxiety disorders (Kandola et al., 2018). Furthermore, participants with lower VO_2max presented a more volatile temperament, anger expression, and lower anger control than those with higher VO_2max, indicating that regular physical exercise can be a useful non-pharmacological strategy for anger management. Similar results have been presented in studies involving stressful occupations, such as firefighters (Yook, 2019). Conversely, Schilling et al. (2020) did not find an association between feelings of anger during the workday and CRF; this disparity may be because the instrument used to assess anger was the single item "How angry did you get during the last 10 minutes?"—this may not be sufficiently able to evaluate anger more vertically. Nonetheless, they found reduced physiological stress reactivity during working hours in police officers with higher CRFs and positively associated higher levels of CRF with parasympathetic activity (assessed with heart rate variability at night, following the workday).

From a theoretical perspective, these findings may be understood within a psychophysiological framework in which higher cardiorespiratory fitness enhances stress regulation capacity, thereby shaping emotional responses to aversive stimuli. Previous evidence indicates that CRF is positively associated with higher vagally mediated heart rate variability under everyday physical and psychosocial stress, reflecting greater parasympathetic control and more efficient autonomic regulation. Such physiological characteristics are known to support adaptive emotional regulation and faster recovery following stress exposure (Salmio et al., 2024). In parallel, resilience has been proposed as a key psychological mechanism linking CRF to mental health outcomes, as physically fit individuals tend to show greater resistance to stress-related emotional disturbances (Pozuelo-Carrascosa et al., 2017). In sum, heart rate variability appears to capture key aspects of an individual's overall resilience profile (An et al., 2020), and physical activity is consistently associated with more efficient autonomic regulation, reflected by better heart rate variability regulation (Tornberg et al., 2019). Together, these mechanisms suggest that higher CRF may buffer stress-related emotional reactivity by promoting both physiological flexibility and psychological resilience, which is consistent with the lower anxiety and attenuated anger responses observed in individuals with higher VO_2max in the present study. From a resilience perspective, the capacity to regulate both anxiety and anger in response to stressors may represent a key marker of adaptive emotional functioning, whereas elevated or poorly controlled expressions of these emotions may indicate reduced emotional resilience. From a CRF perspective, higher CRF may contribute to more efficient regulation of emotional states by supporting

Table 3
Multiple regression models for estimating trait anxiety, trait anger, and Δ anger.

Split	$r^2_{adjusted}$	Df	p-value	Standard error of estimate	Tolerance	VIF	Durbin-Watson
Trait anxiety = 45.336–0.456 (VO_2max) + 0.691 (trait anger)							
VO_2max	0.405	2, 37	< 0.001	0.131	0.957	1.045	1.292
Trait anger	0.405	2, 37	000.3	0.214	0.957	1.045	1.292
Trait anger = 5.595 + 0.318 (trait anxiety)							
Trait anxiety	0.213	2, 37	0.003	0.099	0.724	1.381	2.113
Δ anger = 4.103–0.241 (VO_2max) + 0.333 (anger-out)							
VO_2max	0.251	2, 37	0.003	0.076	0.999	1.001	1.569
Anger-out	0.251	2, 37	0.040	0.157	0.999	1.001	1.569

Δ anger: difference in state anger between pre and post-unpleasant picture exposition; VO_2max: cardiorespiratory measurement; VIF: variance inflation factor; Df: degrees of freedom; r^2:adjusted: effect size.

physiological and psychological processes involved in stress adaptation, as anger and anxiety may have important role in stress-responsiveness in emotional situations.

ANOVA with between-subjects factor (AA × BA VO_2max) revealed that participants with lower VO_2max had greater anxiety-anger levels after unpleasant sessions relative to participants with higher VO_2max. Multiple regression analysis showed a negative association between VO_2max and Δ anger caused by unpleasant picture exposition. Rimmele et al. (2007) showed no differences in anxiety levels in a comparison between trained versus untrained men. However, after the stressor intervention (Trier Social Stress Test-TSST), the trained men exhibited lower anxiety levels than the untrained ones. Using the same method, Childs and de Wit (2014) found that individuals who reported regular physical activity at least once per week had a lower positive affect decline after a stressor task. Those results suggest that physically active individuals are more resilient to stressful events, specifically in terms of anxiety. However, after a 12-week endurance training program, Klaperski, von Dawans, Heinrichs, and Fuchs (2014) did not find a decrease in trait anxiety or chronic stress in men. These studies used only men in their sample, which could explain why training and higher CRF did not reduce anxiety, as men tend to have lower anxiety than women (Costa et al., 2022; Gao, Ping, & Liu, 2020).

Logistic regression showed that the BA group had a 775% higher risk for passing from intermediate anxiety levels before a pre-unpleasant session to high anxiety levels after an unpleasant session, compared to AA group. This is important because anxiety is a common emotion, and it is considered an adaptive response to stress (Gellman, 2020). The Yerkes-Dodson law dictates that, up to a point, performance increases with physiological or mental arousal. However, when levels of arousal become too high or too low, performance decreases (Gellman, 2020; Yerkes & Dodson, 1908). Therefore, if high CRF protects against a detrimental increase in anxiety in stressful situations and individuals with high CRF remain at the optimal level of anxiety for performance, they could benefit from greater cognitive or physical performance. Future studies should evaluate this hypothesis, testing whether high CRF provides better cognitive performance following a stressful event or other types of performance, such as physical. In addition, other studies should use laboratory instruments to reduce anxiety to identify the performance on three anxiety levels (low, moderate, and high).

Multiple regression analysis of the association of VO_2max and trait anxiety, with trait anger as a covariable, showed that VO_2max is negatively associated with trait anxiety. Rimmele et al. (2007) did not identify differences in trait anxiety in men, comparing trained with untrained, possibly because they used elite endurance athletes, and previous findings suggest that athletes who compete in individual sports can exhibit higher anxiety levels than usual (Pluhar et al., 2019). Shigdel, Stubbs, Sui, and Ernstsen (2019) did not identify an association between CRF and anxiety levels, possibly because they used the Hospital Anxiety and Depression Scale (HADS) to evaluate anxiety symptoms in healthy subjects. The HADS was first developed to assess anxiety and depression severity in medically ill patients and mixes anxiety symptoms with fear and panic (Julian, 2011; Zigmond & Snaith, 1983). On the other hand, trait anger is not associated with VO_2max, McIntyre et al. (2020) divided 119 individuals into two groups, of which one did 12 weeks of aerobic training, and there was no intervention into the other, which was the control group. No differences were found between groups after the intervention, corroborating with our findings that CRF may not play a role on anger levels. However, another study found that higher CRF was associated with lower burnout symptoms and depression, showing a possible resilience to stress (Gerber, Lindwall, Lindegård, Börjesson, & Jonsdottir, 2013). This result is correlated with the association between Δ anger and VO_2max; individuals with higher VO_2max showed a lower Δ anger response to emotional stimuli, indicating possible resilience to acute stress. We also found that anger-out was positively associated with Δ anger. The anger inventory (STAXI) construct shows that anger-out represents the capacity to outsource one's feelings of anger. Therefore, individuals with higher anger-out levels tend to feel more anger momentarily. In addition, trait anger was positively associated with trait anxiety, meaning that the two should be studied together because one can influence the other.

Our study had some limitations. Only subjective instruments (IDATE and STAXI) were used to measure emotional state and trait. The use of a CRF estimation algorithm represents another relevant limitation of the study. Although non-exercise prediction models are widely used in population-based research and show acceptable validity for ranking individuals according to their aerobic fitness, they inherently rely on self-reported information, such as habitual physical activity, body mass index, and perceived functional capacity, which may be biased by inaccuracies in recall or self-perception. Furthermore, estimation equations cannot capture physiological responses normally assessed in direct or indirect VO_2max tests, such as ventilatory thresholds or real-time cardiovascular dynamics. Therefore, the CRF values used in the present study should be interpreted as approximations rather than objective fitness measurements, which may have attenuated the strength of associations observed. Future studies should incorporate direct assessments of VO_2max to enhance the precision and validity of CRF-related findings. Despite the methodological rigor applied to the regression analyses, the relatively small sample size remains an important limitation of the present study. Although our subject-to-variable ratio (10) exceeded the minimum recommended in simulation studies for obtaining stable coefficients in linear regression models (Austin & Steyerberg, 2015), smaller samples inherently reduce statistical power and may limit the generalizability of the findings. The use of adjusted R^2, together with thorough diagnostic checks of normality, homoscedasticity, multicollinearity, and residual behavior, supports the internal consistency of our models; however, caution is warranted when extrapolating these results to broader populations. Future studies with larger and more diverse samples are essential to confirm and extend these preliminary associations between VO_2max, anger expression tendencies, and emotional responses to aversive stimuli.

5. Conclusion

Despite its limitations, our study provides meaningful and robust insights into the relationship between cardiorespiratory fitness and emotional regulation. Our findings indicate that individuals with higher CRF tend to exhibit lower trait anxiety and greater resilience when exposed to emotionally stressful stimuli, reinforcing the growing evidence that physical activity plays an important role in emotional health. While future research would benefit from complementary objective measures, such as electroencephalographic exam or cortisol assessment to further characterize emotional stress responses, and from graded exercise testing with direct VO_2max measurement to strengthen CRF evaluation, these methodological refinements are expected to enhance, rather than undermine, the associations observed in the present study. Overall, our results contribute valuable evidence to the field by highlighting CRF as a potential protective factor in emotional stress regulation.

CRediT authorship contribution statement

Thalles Guilarducci Costa: Writing – original draft, Formal analysis, Conceptualization. **Lucas Carrara do Amaral:** Writing – review & editing, Data curation, Conceptualization. **Naiane Silva Morais:** Writing – review & editing, Data curation, Conceptualization. **Wellington Fernando da Silva:** Writing – review & editing, Data curation, Conceptualization. **Douglas Assis Teles Santos:** Writing – review & editing, Data curation, Conceptualization. **Rodrigo Luiz Vancini:** Writing – review & editing, Formal analysis, Conceptualization. **Carlos Alexandre Vieira:** Writing – review & editing, Formal analysis, Conceptualization. **Mario Hebling Campos:** Writing – review & editing, Formal analysis, Conceptualization. **Marilia Santos Andrade:** Writing – review & editing, Conceptualization. **Beat Knechtle:** Writing – review & editing, Writing – original draft, Conceptualization. **Katja Weiss:** Writing – review & editing, Writing – original draft, Conceptualization. **Ricardo Borges Viana:** Writing – review & editing, Formal analysis, Conceptualization. **Claudio Andre Barbosa de Lira:** Writing – review & editing, Writing – original draft, Project administration, Formal analysis, Conceptualization.

Funding

This research was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior–Brasil (CAPES)–Finance Code 001. CABL and MSA are productivity fellowships at the Conselho Nacional de Desenvolvimento Científico e Tecnológico–Brasil (CNPq). RLV is a productivity fellowship at the Fundação de Amparo à Pesquisa do Estado do Espírito Santo–Brasil (FAPES).

Declaration of competing interest

This research was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior–Brasil (CAPES)–Finance Code 001. TGC is a fellowship at CAPES. CABL and MSA are productivity fellowships at the Conselho Nacional de Desenvolvimento Científico e Tecnológico–Brasil (CNPq). RLV is a productivity fellowship at the Fundação de Amparo à Pesquisa do Estado do Espírito Santo–Brasil (FAPES).

Acknowledgments

The authors thank the participants that gave your time to participate in this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2026.106371.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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