*Journal of the Royal Society of New Zealand*

RESEARCH ARTICLE OPEN ACCESS

# The Effect of an Acute Bout of Self-Selected Intensity Exercise on State Anxiety and Anxiety Sensitivity in Moderately Anxious Individuals

Madeleine Connor[1] | Olivia Harrison[2,3,4] | Elaine A. Hargreaves[1]

[1]School of Physical Education, Sport and Exercise Sciences, University of Otago, Dunedin, New Zealand | [2]Department of Psychology, University of Otago, Dunedin, New Zealand | [3]Translational Neuromodeling Unit, University of Zurich and ETH Zurich, Zurich, Switzerland | [4]Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, United Kingdom

**Correspondence:** Madeleine Connor (Maddie.connor@otago.ac.nz)

**Received:** 25 February 2025 | **Revised:** 12 July 2025 | **Accepted:** 12 July 2025

**Keywords:** aerobic | physical activity | state | stretching | trait | ventilatory threshold | worry

## ABSTRACT

Exercise at a self-selected intensity has been shown to reliably improve affect, but its effect on state anxiety has not been rigorously investigated. Further, the postulated role of anxiety sensitivity within the anxiolytic effect of exercise is not yet fully understood. This study investigated the effect of an acute bout of self-selected intensity exercise on anxiety, anxiety sensitivity, and affect. Inactive adults ($n = 39$) with elevated trait anxiety (Spielberger Trait Anxiety Inventory score ≥ 40) were randomised to undertake either 20 min of self-selected intensity aerobic exercise or static stretching (comparison group). State anxiety and anxiety sensitivity were measured before and after exercise. Affect was measured before, during, and after exercise. Results showed that the aerobic group selected a vigorous intensity (81–83%$HR_{peak}$), while the stretching group exercised at a significantly lower intensity (45–48%$HR_{peak}$). From pre- to post-exercise, state anxiety significantly decreased ($p = 0.002$, $\eta^2 = 0.12$) and affect was significantly more positive ($p = 0.02$, $\eta^2 = 0.07$) across all participants. There were no significant changes to anxiety sensitivity. Results suggest that moderately anxious individuals self-select a vigorous aerobic exercise intensity that results in improvements in state anxiety and affect to the same extent as static stretching of low intensity. Changes to anxiety sensitivity do not appear to explain these effects.

## 1 | Introduction

Elevated anxiety can reduce an individual's capacity for daily functioning and increase their risk of developing an anxiety disorder (Pine et al. 1998; Merikangas et al. 2010). Notably, 16% of New Zealand's population regularly experience moderate-to-high levels of state anxiety (Every-Palmer et al. 2020), although not all have a clinical diagnosis and would instead be described as having subclinically elevated anxiety. Systematic review evidence has demonstrated the potential for an acute bout of exercise to reduce state anxiety and highlights the variety of exercise modalities, intensities, and durations that can be effective (Petruzzello et al. 1991; Ensari et al. 2015; Connor et al. 2023). For example, 20 to 30 min of moderate-to-vigorous intensity aerobic exercise (e.g. Cooper and Tomporowski 2017; Herzog et al. 2022) has been demonstrated to reduce state anxiety, as well as both lower (e.g. Breus and O'Connor 1998) and higher (e.g. Cox et al. 2004) intensities. As many different exercise stimuli have been effective in reducing anxiety, it may be appropriate to utilise self-selected exercise intensities. A self-selected exercise intensity is likely valuable for decreasing state anxiety because it accounts for individual preferences, and minimises the risk of experiencing negative affective responses during and following exercise, supporting overall positive psychological wellbeing (Jung et al. 2014). However, this approach has yet to be sufficiently investigated with respect to its potential to result in state anxiety reductions.

Although underutilised in the exercise-anxiety literature, the use of self-selected intensities as a means of improving affect—a key component of psychological well-being—is well established (e.g. Rose and Parfitt 2007; Ekkekakis et al. 2013; Jones and Zenko 2023). The Dual Mode Model (Ekkekakis 2003) explains how the balance of the physiological symptoms of exercise (interoceptive cues) and cognitive appraisal are instrumental in forming affective responses to exercise. The contribution of each varies according to exercise intensity. Physiological signals from the body increase their dominance as intensity increases from moderate to higher intensities (classed as at and above ventilatory/anaerobic threshold [VT]), while intensities below and up to VT rely more heavily on an individual's cognitive appraisal for the affective response (see Ekkekakis 2003 and Williams 2008 for further details). When self-selecting an intensity, individuals tend to self-select a moderate intensity around VT (e.g. Rose and Parfitt 2012; Hamlyn-Williams et al. 2014; Zenko et al. 2020). It is proposed that this occurs as individuals appraise the exercise, including the interoceptive cues, to select an intensity that will result in a positive affective response (Rose and Parfitt 2007).

The effect of self-selected exercise intensities to improve anxiety is less well established. Four previous studies have investigated the effect of self-selected intensity exercise on anxiety, three in university aged students (Focht and Hausenblas 2001; Szabo 2003; Meier and Welch 2016) and one in a group with clinical anxiety (Knapen et al. 2009). However, none of the studies adequately reported the intensity of exercise chosen. Two demonstrated the anxiolytic effect of exercise at a 'preferred' intensity, but the authors did not describe the specific intensity participants selected (Focht and Hausenblas 2001; Szabo 2003). In further analysis, Focht and Hausenblas (2001) showed that improvements to state anxiety were restricted to those with higher levels of state anxiety at baseline, likely due to floor effects in those with lower anxiety levels. Meier and Welch (2016) utilised walking at a self-selected intensity in students with elevated anxiety. They did not report the intensity selected and found no effect of the walking on state anxiety, suggesting that an intensity higher than what can be achieved by walking may be necessary. Lastly, Knapen et al. (2009) evaluated the effect of self-selected intensity exercise on state anxiety in a sample of individuals with a clinical diagnosis of depression or anxiety. While significant improvements in state anxiety were observed, exercise intensity was reported as absolute (beats per minute), rather than as a percentage of their maximum heart rate. However, by considering the average age of participants, it appears that they exercised at an intensity approximately 77% of age predicted-HRmax. Consequently, no study including participants with subclinically elevated anxiety has appropriately evaluated the intensity participants select to exercise at, nor the influence this may have on state anxiety.

In those with elevated trait anxiety, it is also common to experience worry about anxiety symptoms, termed anxiety sensitivity (McLaughlin and Hatzenbuehler 2009; Naragon-Gainey 2010). Anxiety sensitivity is a modifiable trait-like factor (Robinson and Freeston 2014) heavily implicated in the advancement of anxiety, with anxiety sensitivity accounting for over a third of anxiety disorder symptomology (Abrantes et al. 2012; Robinson and Freeston 2014). While conceptualised as a trait-like construct (Robinson and Freeston 2014), anxiety sensitivity has been shown to respond to acute interventions, reinforcing its modifiable nature (e.g. Mason and Asmundson 2018). Anxiety sensitivity can be measured as a single overarching construct and is often measured using the Anxiety Sensitivity Index 3 (ASI-3; Taylor et al. 2007). The ASI-3 is broken down into three sub-scales of cognitive, social, and physical symptoms. Cognitive anxiety sensitivity is associated with worry about severe mental illness, while the social domain concerns fear around social judgement or rejection. Physical anxiety sensitivity relates to specific concerns about the consequences of bodily anxiety symptoms, for example fear that a racing heart will lead to a heart attack. As exercise can elicit many of these same physical symptoms in a different context to anxiety (Wallman-Jones et al. 2021), it has been postulated that exercise participation may reduce anxiety sensitivity and lead to improved overall anxiety (Sabourin et al. 2015).

Previous research has shown an acute bout of exercise can reduce overall anxiety sensitivity (LeBouthillier and Asmundson 2015; Mason and Asmundson 2018), with higher intensities (e.g. sprint intervals at ≥85% age predicted-HRmax) necessary to specifically reduce the physical domain (Mason and Asmundson 2018). Despite the potential benefits of high intensity exercise for anxiety sensitivity, those with elevated anxiety sensitivity self-report less engagement in high intensity physical activity—this could be explained by a desire to avoid the arousal experience of exercise and the symptoms it generates (McWilliams and Asmundson 2001). However, when allowed to self-select their intensity, individuals appear more tolerant to vigorous exercise (Ekkekakis et al. 2011). This may mean that they are more likely to approach the intensity required to reduce anxiety sensitivity with less worry, likely due to enhanced feelings of control (Vazou-Ekkekakis and Ekkekakis 2009). Further, as intensity self-selection during exercise is thought to involve the monitoring of afferent signals from the cardiorespiratory and muscular systems (Roelands et al. 2013; Avancini et al. 2025), self-selected intensity exercise may encourage a focus towards—and reappraisal of—afferent physiological signals. The focus towards the exercise itself may be key, as interoceptive interventions utilising 90 s of self-induced hyperventilation that aimed to reduce anxiety sensitivity were only found to be effective when coupled with cognitive restructuring tasks (Carter et al. 1999). While our present study does not contain a specific cognitive restructuring task, this may be implicitly encouraged by the process of self-selecting an intensity. Moreover, as the individual is likely to be experiencing a positive affective response, they may reflect upon these symptoms with less associated anxiety. However, no studies have yet investigated the effect of self-selected intensity exercise on anxiety sensitivity. For exercise to encourage the reappraisal of physical sensations required to reduce anxiety sensitivity as a contributing factor towards improvements in state anxiety, participants may need to 1) reach an intensity sufficient to produce the anxiety-like physical sensations, 2) pay particular attention to these symptoms while exercising, and 3) feel that they are in control of, and have the capability to manipulate, the symptoms arising in their bodies.

Therefore, the objectives of this study were to investigate 1) how self-selected intensity aerobic exercise (compared to stretching) influenced state anxiety, anxiety sensitivity, and affect; 2) the intensity that inactive individuals with elevated levels of trait anxiety will self-select in the aerobic condition, and if intensity changes over the exercise bout; and 3) whether participants are paying specific attention to the exercise or not, and if they report feeling in control of their body symptoms. It was hypothesised that the individuals in the aerobic condition would select a moderate exercise intensity at approximately VT, resulting in a decrease in state anxiety and more positive affect from pre- to post-exercise. Participants in the stretching group were also expected to experience a decrease in state anxiety and more positive affect from pre- to post-exercise, although to a lesser extent than the aerobic group. Changes in affect between groups and over time during exercise were also explored. If the exercise intensity chosen in the aerobic condition was high enough to elicit improvements in anxiety sensitivity, it was expected that the aerobic group would experience greater reductions in the physical domain of anxiety sensitivity compared to the stretching group due to the differing salience of interoceptive signals present with aerobic exercise. Further, throughout exercise, it was expected that participants in the aerobic group would report more associative thoughts and less control of their body symptoms compared to the stretching group.

## 2 | Methods

### 2.1 | Participants

Participants were recruited through social media advertising, email advertisements across university department mailing lists, posters within student residential halls, and through a research participation system which offered credit to undergraduate psychology students. All interested participants were directed to a pre-screening survey. To be eligible for the study, participants were required to score $\geq 40$ on the trait scale of the Spielberger state-trait anxiety inventory (STAI-T; Spielberger et al. 1983) indicating above average trait anxiety levels (Skapinakis 2014). In addition, participants had to be aged 18–46 years old (due to alterations in anxiety experiences that can occur through menopause; Alblooshi et al. 2023), have exercised less than once a week on average over the last 6 months, have no chronic medical disorders, not be taking regular medications, did not smoke or vape more than once a week, and had no contraindications to exercise as determined by the Physical Activity Readiness Questionnaire (Warburton et al. 2011). As shown in Figure 1, 550 individuals expressed interest in participating and completed an online pre-screening questionnaire which contained the measures to assess eligibility (i.e. pre-screening questions as well as STAI-T and PAR-Q+ questionnaires). Of those 550 who completed the pre-screening questionnaire, 78 were eligible and 39 competed the protocol. The sample size recruited allowed for 90% power to detect a moderate effect size of $f = 0.4$ (derived from previous literature; Broman-Fulks et al. 2015) using a $2 \times 2$ repeated measures ANOVA with a two tailed alpha of 0.05 (calculated using G*Power; Faul et al. 2007).

Once participants were recruited, they were assigned an identification number (ID) that had previously been randomly assigned to either the aerobic (AER) or stretching (STR) condition through a

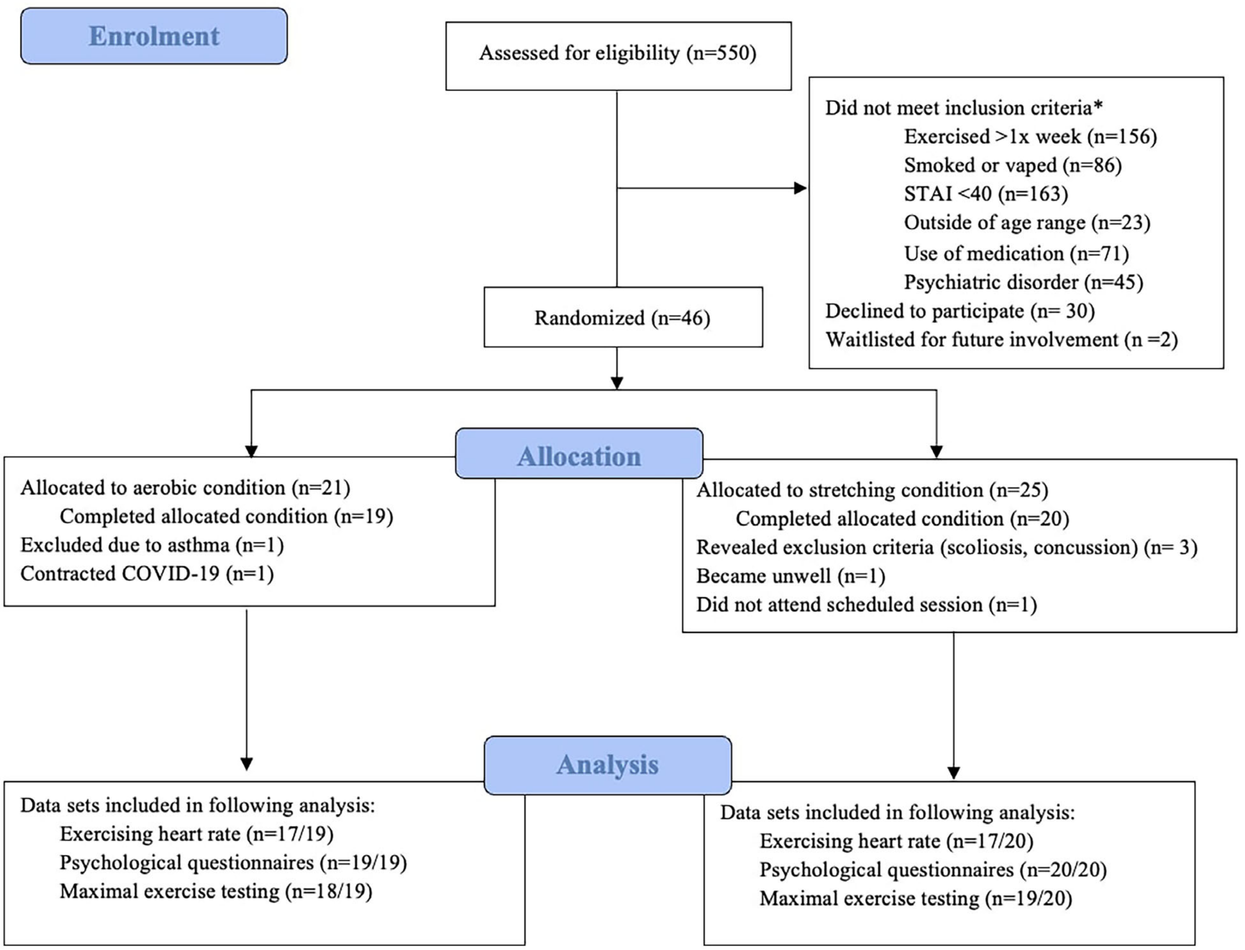


**FIGURE 1** | Flow diagram of participants throughout study progression.
*Note:* *Multiple participants met more than one exclusion criterion.

Microsoft Excel matrix. Blinding could not occur at either the researcher or participant level due to the demands of the researcher to deliver the experimental activities. However, participants were not aware if the protocol they completed was intended to be the active/exercising group or the comparison group.

## 2.2 | Measures

### 2.2.1 | State–Trait Anxiety

Both state and trait anxiety were assessed using the State–Trait Anxiety Inventory (STAI; Spielberger et al. 1983). The STAI is made up of two 20-item subscales: state and trait anxiety. Each item asks how much the individual agrees with each item either 'at the present moment' to indicate state anxiety, or 'generally' to indicate trait anxiety. Participants responded on a 4-point Likert scale, ranging from 1 (not at all, state; almost never, trait) to 4 (very much so, state; almost always, trait). Ten of the state items and nine of the trait items are inversely scored. Individual responses for each subscale were summed with potential scores ranging from 20 to 80, where a score above 40 on either scale was taken as indicative of moderate anxiety (Skapinakis 2014). The STAI-T has shown high test–retest reliability (0.97; Metzger 1976), while the STAI-S has demonstrated reliable discrimination between individuals in high- and low-stress settings (Metzger 1976; Skapinakis 2014).

### 2.2.2 | Anxiety Sensitivity

Anxiety sensitivity was assessed using the Anxiety Sensitivity Index-3 (ASI-3; Taylor et al. 2007). The ASI-3 comprises 18 items that concern an individual's appraisal of an experience or emotion they may experience, for example 'it scares me when my heart beats rapidly'. Each item in the index relates to one of the three domains of anxiety sensitivity: cognitive, social, physical. Participants indicated the extent to which they agree or disagree with each item on a five-point Likert scale which ranges from 0 (don't agree at all) to 4 (completely agree). Additional anchors are agree a little (1), partly agree (2), and pretty much agree (3). The index was scored according to overall anxiety sensitivity and as scores for the three domains/components. Scoring for both the total score and domains/components was achieved by summing responses to relevant items. Each subscale has 6 items giving a potential total ranging from 0 to 24; overall anxiety sensitivity score ranges from 0 to 72. An overall anxiety sensitivity score of ≥23 is considered to represent high overall anxiety sensitivity (Olthuis et al. 2014). The ASI-3 has been shown to demonstrate sound construct validity with appropriate reliability (reliability coefficient = 0.85; Kemper et al. 2012).

### 2.2.3 | Affect

The Feeling Scale (FS; Hardy and Rejeski 1989) measured each participant's affective valence, capturing their broad sense of pleasure or displeasure (Hardy and Rejeski 1989). Participants indicated how they felt on a scale from + 5 (very good), to −5 (very bad) with additional anchors at + 3 (good), +1 (fairly good), 0 (neutral), −1 (fairly bad), and 3 (bad). The Feeling Scale has demonstrated appropriate construct validity, including a 0.41–0.59 correlation with the valence scale of the Affect Grid (Van Landuyt et al. 2000), and is widely utilised when researching affective responses to exercise (Bok et al. 2022).

### 2.2.4 | Ratings of Perceived Exertion

The Borg Ratings of Perceived Exertion (RPE) Scale (Borg 1970) is widely used within exercise settings to indicate how hard the individual feels they are exercising. The scale ranges from 6 to 20 with anchors placed at 7 (very, very light), 9 (very light), 11 (fairly light), 13 (somewhat hard), 15 (hard), 17 (very hard), and 19 (very, very hard). The scale is widely used and is recognised to have good validity across a variety of populations (0.8–0.9; Chen et al. 2002) and is reliable (Ritchie 2012).

### 2.2.5 | Measures of Control of Body Symptoms and Perceived Association/Dissociation

Visual analogue scales similar to those previously used in Baden et al. (2004) were utilised to assess individuals' perceived control of their body symptoms and the perceived proportion of associative/dissociative thought content of the previous few thoughts. A score of zero represents entirely associative thoughts, or complete control, and ten represents entirely dissociative thoughts, or completely out of control. The scales were explained to participants prior to measurement. Associative thoughts were explained as those relating to the body and the feelings they had in their body during exercise, with examples such as feeling their heart rate or noticing discomfort in an area of their body. Dissociative thoughts were described as those unrelated to the body or 'day-dreaming'. It was explained that if a thought begins as associative (e.g. this hurts my feet), but the following thoughts become dissociative (e.g. maybe I should get new shoes, I'll go on Saturday, etc.), only the original thought is associative, and the overall proportion may be more dissociative. Control of body symptoms was described as their perceived ability to manipulate or contain their body symptoms with the example of feeling able to speed up or slow down their breathing if they desired to, if they were able to manipulate their breath this would indicate control, whereas an inability represented a lack of control.

## 2.3 | Procedures

Participants completed two individual sessions within 3–7 days of each other. The format of each session is shown in Figure 2. Session one was the aerobic exercise or stretching session, and in session two participants undertook a graded exercise test to enable the exercise intensity of session one to be quantified according to VT and maximal exercise capacity. When participants arrived at the laboratory for the first session, their eligibility was confirmed. They were then briefed on the first session's structure and fitted with a Polar H10 heart rate monitor (Polar H10, Polar Electro inc., Port Washington, NY) to be worn throughout the exercise session. Prior to beginning the exercise, participants completed the STAI-S, ASI-3, and FS. Following this, the RPE, control of body symptoms, and associative/dissociative thoughts measures were explained to the participant, with time to ask questions. The participant then engaged in their respective exercise bout. RPE, FS, control of body symptoms, and proportion of associative thought were collected prior to beginning exercise (0 min), halfway through (10 min), and at the end (20 min) of the exercise bout. Note that the aerobic group also included a 5-min warm-up prior to the exercise starting and 5-min cool-down period following cessation of the exercise for safety precautions, where warm-up and cool-down time were not included in

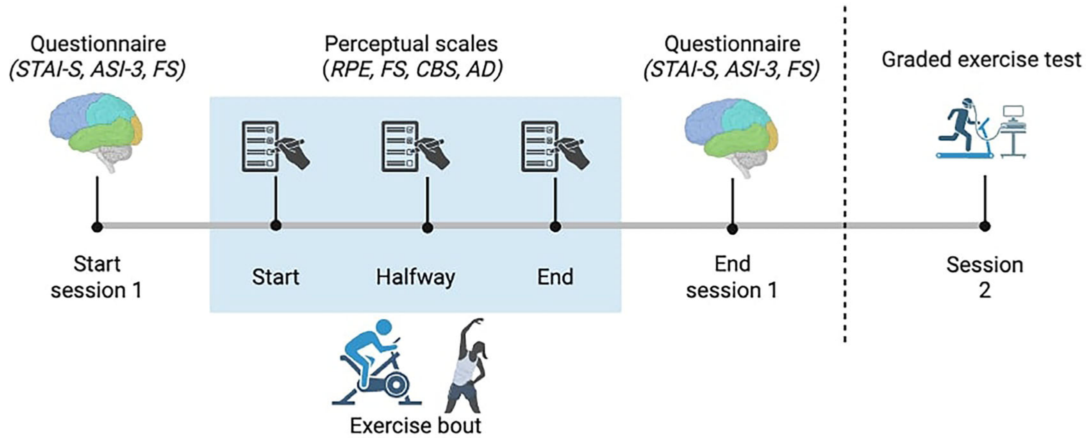


**FIGURE 2** | Visualisation of measures throughout experimental sessions. Post-exercise questionnaires were completed no less than 5 min following completion of the exercise bout.

the 'exercise bout' when determining timing of scales (i.e. for halfway and end measures). Participants were informed when the warm-up and cool-down periods started and finished. No less than 5 min following the cessation of the exercise bout participants repeated the STAI-S, ASI-3, and FS. Both experimental sessions were completed in a controlled laboratory with no music provided and only the participant and two researchers present. Heart rate was recorded continuously to assess changes to the selected intensity across time. Data related to treadmill incline/speed or cycle power output were not recorded.

### 2.3.1 | Self-Selected Intensity Aerobic Group

Participants selected whether they completed the session on a cycle ergometer or a treadmill. Of the 19 participants in this group, 11 chose the stationary cycle. Participants were shown how to manipulate the intensity on their chosen equipment and were instructed to exercise at a self-selected intensity using an adaptation of the instructions used by Zenko et al. (2020). Specifically, participants were told:

> *"For today's exercise session, you will be exercising for 30 minutes including a five minute warm-up and cool-down. I'll be asking you questions about how you feel and how hard you perceive the exercise to be. I'll also be measuring your heart rate. The exercise intensity that you choose is up to you the entire time. You can adjust the treadmill speed or incline at any time you choose. Do you have any questions?"*

No limit was placed around the speed of either apparatus, nor the incline of the treadmill. No further instructions were provided regarding an expectation of the intensity for the warm-up or cool-down periods. Participants were, however, informed when these periods were beginning and had ended.

### 2.3.2 | Stretching Condition

Participants were led through 20 min of static stretching with 15 stretches held for 30 s each, with 30-s rest between each. Stretches moved through the whole body and were completed in seated, standing, and reclined positions as required. The specific stretches can be found in the supplementary materials. For the 10 unilateral stretches, the opposite limb was stretched immediately following the other without the 30s rest between. The experimenter verbally explained and physically modelled the stretches alongside the participant. Participants in the stretching condition were free to choose the intensity of the stretch. Interactions between researchers and participants were limited to those necessary to obtain measurements and give instructions.

### 2.3.3 | Graded Exercise Test

Participants returned to the lab between 3 and 7 days later to complete an incremental maximal exercise test to determine their maximal oxygen consumption ($VO_{2max}$), maximum heart rate ($HR_{max}$), and ventilatory threshold (VT). This was used to characterise participants' fitness, as well as the exercise intensity they selected as a percentage of their maximum heart rate and relative to VT. For those in the AER condition, this was completed on the same equipment (stationary cycle or treadmill) they had chosen for their exercise in the previous session. Those in the STR condition chose either the treadmill or cycle (14/20 chose the treadmill). Heart rate was monitored using a Polar H10 (Polar H10, Polar Electro inc., Port Washington, NY) with expired and inspired air monitored by an online gas analysis system (Cardio-Pulmonary Exercise Testing [CPET], Cosmed, Rome, Italy). For those who selected the cycle, they first cycled for 3 min at 50W. Each min thereafter the workload was increased by 15–25 W. Those who selected the treadmill followed a modified Balke–Ware treadmill graded exercise test protocol (Balke and Ware 1959). The first 3 min were completed at 4 km/h with 0% incline. Each min thereafter the intensity was increased alternately by either 0.5 km/h or 1%–2% in incline. All tests aimed to allow the participant to reach maximal intensities without undue strain or risk of injury. Incremental increases were adjusted according to the participant's physiological and perceptual responses to the exercise with the aim to complete the protocol in under 15 min to avoid undue strain.

## 2.4 | Data Analysis

Heart rate at the beginning, halfway, and end of each exercise condition was extracted (averaged across 10-s periods) to compare alongside the perceptual responses recorded at the same timepoints. This was then quantified as a percentage of the peak HR ($HR_{peak}$) obtained in the incremental exercise test. Because the aerobic condition contained a 5-min warm-up and 5-min cool-down period on top of the 20-min active exercise period, halfway was deemed to be 10 min into the 20-min active exercise period and end of exercise was deemed to be 25 min. Peak heart rate ($HR_{peak}$) was identified as the maximum value, and peak volume of oxygen consumed ($\dot{V}O_{2peak}$) calculated by averaging the 30 s around the highest value.

VT was identified by two analysts using the v-slope method (Gaskill et al. 2001) to identify the first inflection point in the $\dot{V}O_2/\dot{V}CO_2$ relationship. If there was disagreement between the two analysts, this was discussed and a third opinion requested—although this situation did not arise. Using R, each heart rate reading throughout exercise was identified to be either at (95%–105% of VT), above (≥105%), or below (<95%) VT, with the proportion of session time then calculated to describe the exercise intensity relative to VT. This was expressed as descriptive statistics. Two participants were excluded from VT analysis and $HR_{peak}$ analysis due to missing accurate HR data. The other variables that were collected via questionnaire from these participants were included in the analysis as the primary objective was to evaluate change in state anxiety, and all participants were expected to improve in anxiety.

Analysis was completed in R and RStudio (versions 4.4.1 and 2024.04, respectively). State anxiety, anxiety sensitivity, $\%HR_{peak}$, RPE, affect, associative/dissociative thought, and control of body symptoms were compared using group (AER vs STR) by time (pre-, during, post-exercise) type II repeated measures ANOVAs in R (car package) with Greenhouse-Geisser corrections applied. Anxiety sensitivity was analysed as both total score and the score for each of the subscales. All datasets were assessed for homogeneity of variance using a Levene test (rstatix package), as well as for parametric distribution using a Kolmogorov–Smirnov test. Both assumptions were fulfilled. Tukey post-hoc tests were used to identify the direction of significant ANOVA results to assess both the difference between groups and change over time for variables which may have fluctuated over time (applied to $\%HR_{peak}$, RPE, and exercising affect). Planned contrasts were utilised for variables where directional hypotheses had been formed (STAI, ASI, associative/disassociate thought, and control of body symptoms), with estimated marginal means evaluated in the R emmeans package. Contrasts included pairwise comparisons between conditions at each timepoint, within-group changes across timepoints (simple effects) and interaction contrasts to assess whether changes over time differed by condition. No corrections were applied. Partial eta squared effect sizes were derived for anxiety and anxiety sensitivity outcomes using the effectsize package and interpreted according to the guidelines described in Lakens (2013): small = 0.01, medium = 0.06, and large = 0.14.

## 3 | Results

### 3.1 | Participant Characteristics

Table 1 shows the demographics of participants who completed the study. There were no between-group differences in any of the measured variables. Most participants identified as female, with one AER and two STR participants identifying as a gender other than male or female. All participants met the criteria for elevated trait anxiety. The average $\dot{V}O_{2peak}$ across all participants would be considered poor (Buttar et al. 2022), congruent with participants self-reported inactivity. There were no significant differences in $\dot{V}O2_{peak}$ between those who completed the maximal exercise test on the treadmill (M = 35.8, SD = 0.5) or on the cycle ergometer (M = 30.4, SD = 7.2; $t[37] = -1.82$, $p = 0.07$).

Sensitivity analyses were carried out to examine whether those who were excluded in the HR analyses due to inadequate data quality influenced the results of the STAI-S and ASI analyses, whereby these were re-run with these individuals also excluded. These results demonstrated no change to significance or effect sizes (see supplementary material); therefore, we retained all participants with available data in the presented analyses.

### 3.2 | Selected Intensity

#### 3.2.1 | $\%HR_{peak}$ and Ventilatory Threshold

There was a significant group by time interaction ($F[2] = 41.98$, $p < 0.01$) for $\%HR_{peak}$ (see Figure 3A). Post-hoc analysis of the interaction found that $\%HR_{peak}$ was not significantly different at baseline between groups (M ± SD: 47.44% ± 7.04%; $p = 0.23$). However, $\%HR_{peak}$ was significantly higher in the AER group compared to the STR group at the midpoint (AER: 81.2% ± 10.7%; STR: 45.4% ± 5.6%) and end (AER: 83.5% ± 11.2%; STR: 48.5% ± 7.0%) of exercise.

When comparing exercise intensity according to VT, the AER group on average selected to spend 88.35% of their time exercising at an intensity above VT, with the remainder spent at VT

**TABLE 1** | Participant demographic information.

| Characteristic | AER ($n = 19$) | STR ($n = 20$) | Whole group ($n = 39$) | Between group difference analyses |
|---|---|---|---|---|
| Age (years) | 28.7 (8.78) | 26.5 (7.64) | 27.6 (8.2) | $t(37) = 0.83$, $p = 0.41$ |
| Gender (% female) | 63% ($n = 12$) | 70% ($n = 14$) | 66% ($n = 26$) | $t(37) = 0.33$, $p = 0.70$ |
| Education (years) | 16.6 (2.6) | 16.2 (3.6) | 16.4 (3.1) | $t(37) = -0.39$, $p = 0.69$ |
| **$\dot{V}O_{2peak}$ (mL/min/kg)** | 31.9 (8.9) | 35.0 (10.0) | 33.5 (9.5) | $t(37) = -1.01$, $p = 0.31$ |
| **$HR_{peak}$ (BPM)** | 176 (24) | 178 (29.9) | 177 (26) | $t(35) = -0.22$, $p = 0.82$ |
| VT (mL/min/kg) | 19.6 (4.7) | 20.9 (6.8) | 20.3 (5.8) | $t(35) = -0.68$, $p = 0.49$ |
| **$\%HR_{peak}$ at VT** | 73.0 (7.9) | 72.6 (6.5) | 72.8 (7.2) | $t(35) = -0.13$, $p = 0.89$ |
| STAI-Trait | 52.7 (7.1) | 54.6 (9.6) | 53.7 (8.4) | $t(37) = -0.72$, $p = 0.47$ |

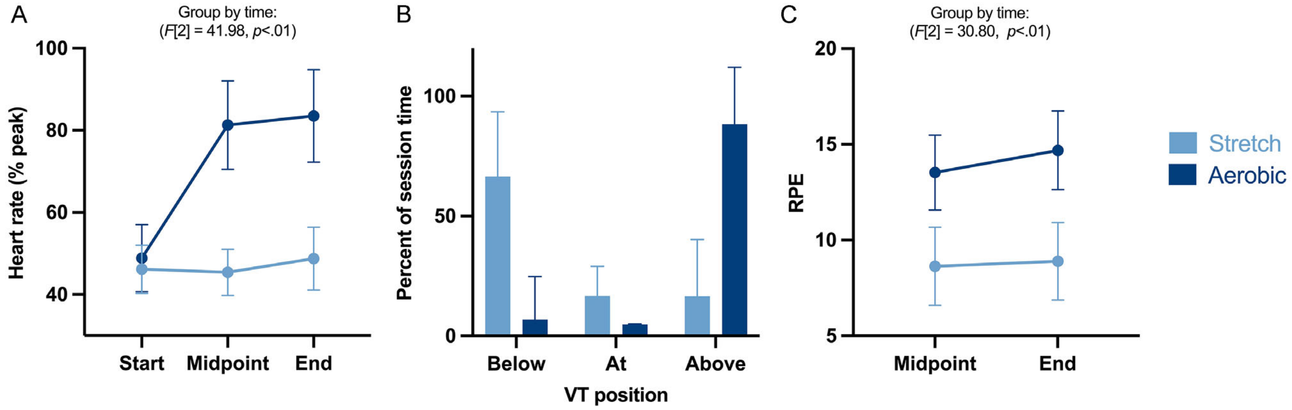


**FIGURE 3** | Objective and subjective intensity measures throughout exercise. (A) %$HR_{peak}$ at the start, midpoint and end of exercise. (B) Percentage of exercise time spent below, at and above ventilatory threshold. (C) Ratings of percieved exertion at the midpoint and end of exercise.

(4.88%) and below VT (6.76%). The STR group spent 16.63% of their time at an intensity above VT, with the remainder of time spent at VT (16.70%) and below VT (66.75%) (see Figure 3B). There was no difference in %$HR_{peak}$ ($F[1] = 2.08$, $p = 0.15$), or proportion of VT ($F[1] = 1.97$, $p = 0.16$) between those that chose to exercise on the cycle ergometer or treadmill.

#### 3.2.2 | RPE

There was a significant group by time interaction ($F[2] = 30.80$, $p < 0.01$) (Figure 3B) for RPE. Post-hoc analysis showed that RPE was significantly higher in the AER compared to the STR group at the midpoint (M ± SD, AER: 13.4 ± 1.9; STR:8.0 ± 2.9) and end (AER: 14.5 ± 2.3; STR: 8.23 ± 2.9) of exercise (see Figure 3C). No differences were observed for RPE or %$HR_{peak}$ between the AER participants who selected the cycle ergometer or treadmill.

### 3.3 | Effect on Psychological Outcomes

#### 3.3.1 | State Anxiety

There was a significant time main effect for state anxiety ($F[1] = 9.97$, $p < 0.01$; Figure 4A) with a large effect size ($\eta^2 = 0.12$). The results of the planned contrasts indicated that state anxiety significantly reduced in both the aerobic ($t[74] = -2.15$, $p = 0.03$) and stretch ($t[74] = -2.31$, $p = 0.02$) conditions from pre- (M ± SD: 44.7 ± 9.8) to post-exercise (37.5 ± 9.9). There was no group main effect ($F[1] = 0.88$, $p = 0.3$) or group by time interaction ($F[1] = 0.004$, $p = 0.94$).

#### 3.3.2 | Anxiety Sensitivity

There was a small to moderate ($\eta^2 = 0.04$) reduction in anxiety sensitivity from pre- (M ± SD: 40 ± 13.1) to post-intervention (M ± SD: 34.4 ± 14.7) that approached significance ($F[1] = 3.04$,

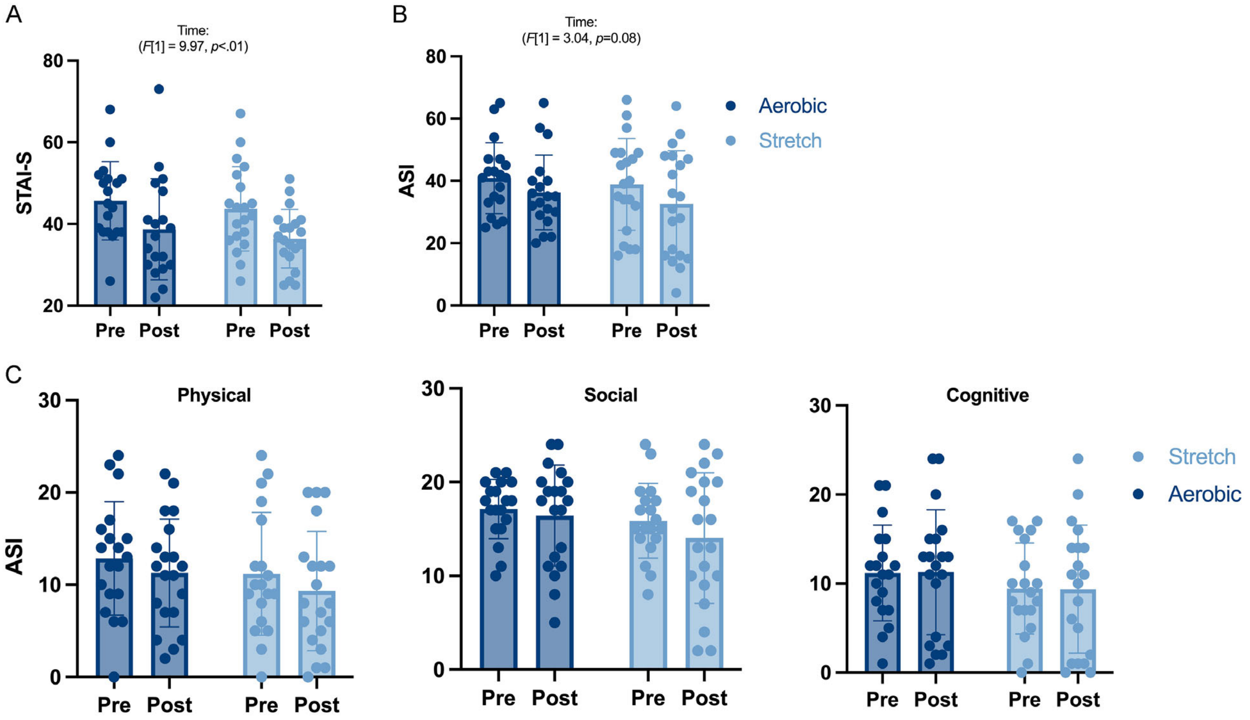


**FIGURE 4** | State anxiety and anxiety sensitivity scores before and after exercise. (A) State anxiety scores. (B) Total anxiety sensitivity. (C) Anxiety sensitivity subscales: Physical, Social, and Cogntive.

$p = 0.08$; Figure 4B). These results were reflected in the planned contrasts, with no significant changes from pre- to post-exercise for anxiety sensitivity in either group (AER: $t[74] = -1.05$, $p = 0.30$; STR: $t[74] = -1.41$, $p = 0.16$). There was no significant group main effect ($F[1] = 0.85$, $p = 0.35$) or group by time interaction ($F[1] = 0.08$, $p = 0.92$).

There were no significant main effects or interactions for the physical, social, and cognitive subscales of anxiety sensitivity. These results were reflected in the planned contrasts, with no significant changes from pre- to post-exercise for physical anxiety sensitivity in either group (AER: $t[74] = 0.83$, $p = 0.41$; STR: $t[74] = 0.98$ $p = 0.33$). (Figure 4C).

### 3.3.3 | Affect

A significant time main effect occurred for affect ($F[4] = 3.80$, $p < 0.01$) (Figure 5). No significant group ($F[1] = 0.99$, $p = 0.32$) or group by time ($F[4] = 0.86$, $p = 0.48$) effects were observed. Planned contrasts found a significant difference between pre-exercise (M ± SD, $1.74 \pm 1.87$) and post-exercise affect ($2.62 \pm 1.44$, $t[74] = 2.28$, $p = 0.02$).

No significant time ($F[2] = 0.32$, $p = 0.73$), group ($F[1] = 0.25$, $p = 0.62$), or group by time ($F[2] = 2.43$, $p = 0.09$) effects occurred for affect during exercise.

### 3.3.4 | Control of Body Symptoms

There was a significant group main effect ($F[1] = 10.94$, $p = < 0.01$) (Figure 6), a significant group by time interaction ($F[2] = 3.8$, $p = 0.02$), and a time main effect which approached significance ($F[2] = 2.96$, $p = 0.06$) for control of body symptoms. Planned contrasts found a significant difference between conditions at halfway through (AER: $4.0 \pm 1.5$, STR: $2.3 \pm 1.8$; $t[96] = 2.24$, $p = 0.02$) and the end of exercise (AER: $4.8 \pm 2.4$, STR: $2.0 \pm 1.4$; $t[96] = 3.67$, $p < 0.01$), with no significant differences at baseline (M ± SD, AER: $2.3 \pm 1.7$, STR: $2.4 \pm 2.1$; $t[96] = -0.18$, $p = 0.85$). Overall, control of bodily symptoms was higher (indicating less control) in the in AER condition compared to the STR condition, suggesting that while the aerobic group decreased in control of body symptoms throughout, the stretching group remained stable.

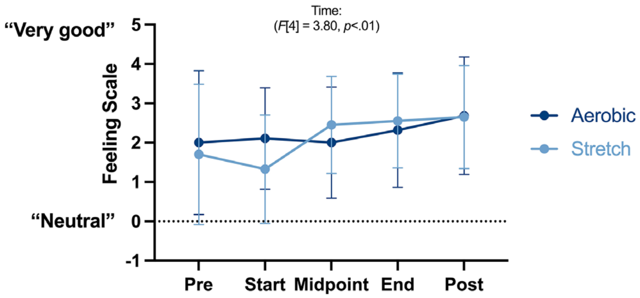


FIGURE 5 | Affective responses to exercise.

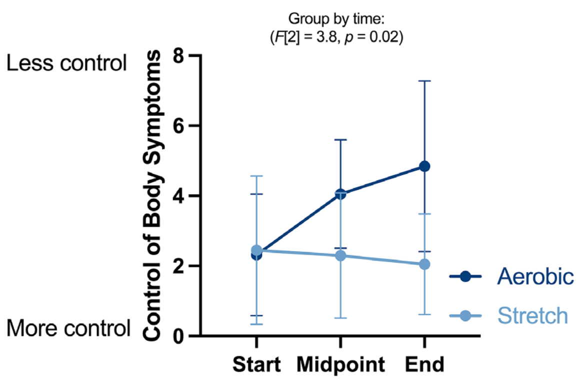


FIGURE 6 | Reported control of body symptoms throughout exercise.

### 3.3.5 | Association/Dissociation

There were no significant time ($F[2] = 2.0$, $p < 0.05$) or condition main effects ($F[1] = 0.76$, $p = 0.36$) or a group by time interaction ($F[2] = 0.52$, $p = 0.28$) for associative/dissociative thought content. Throughout both conditions, individuals reported an even proportion of associative/dissociative thought (M ± SD, AER: $4.4 \pm 2.3$, STR: $4.4 \pm 2.3$).

## 4 | Discussion

This study found that an acute bout of aerobic exercise and stretching both reduced state anxiety and improved positive affect in those with subclinically elevated anxiety. In contrast, results showed only a trend towards improvements in anxiety sensitivity. On average, participants in the aerobic condition self-selected to exercise at 81–83%$HR_{peak}$ (indicative of vigorous intensity), with 88% of their exercise time spent at an intensity above their VT. There was no difference between groups or across time in reported associative/dissociative thought content, although the aerobic group reported less perceived control of body symptoms across time compared to the stretching group.

Aerobic participants in this study selected a more vigorous intensity than expected. Previous research in the affect context (where anxiety has not been measured) has found participants to select a moderate intensity (ranging from 68 to 72%$HR_{max}$, e.g. Ekkekakis and Lind 2006; Rose and Parfitt 2012; Hamlyn-Williams et al. 2014, Zenko et al. 2020), which has been characterised as approximately equating to participants' VT. In particular, the study by Zenko et al. (2020) used similar instructions and had a sample similar in both inactivity and age to the current cohort, suggesting the higher intensity selected in the current study may be associated with the elevated anxiety levels of our participants. In contrast, in previous research with clinically anxious individuals, although exercise capacity was not directly measured, the intensity selected was estimated to be near 77% age-predicted $HR_{max}$, (Knapen et al. 2009). Therefore, subclinically anxious individuals appear on average to select more vigorous intensities than that previously reported in nonanxious populations.

The aerobic and stretching groups both had similar reductions in state anxiety following the acute bout of exercise. Previous research that has demonstrated improvements with exercise superior to a control condition has typically employed quiet rest/documentary watching comparison conditions (e.g. Butki et al. 2001; Herzog et al. 2022). These comparisons may result in rumination which can worsen anxiety (Herzog et al. 2022) and do not allow for the sense of achievement or confidence building that can be attained through exercise or exercise-adjacent comparison activities (i.e. stretching) which have been linked to improved anxiety (Besio 2003). Furthermore, positive affect was also shown to improve to a similar extent across both groups, which has recently been suggested to mediate changes in state anxiety (Herzog et al. 2022). Therefore, although the similar anxiety improvements between groups was unexpected, there are potential explanations for the finding that should be explored in future research. For example, whether affect mediates the anxiolytic effect should be explored in a sample powered to detect the direction of this relationship.

There was no change to anxiety sensitivity in either group following exercise. This may be because the exercise intensity chosen by the aerobic group (81–84%$HR_{peak}$) approached (but did not exceed) levels previously shown to be sufficient to reduce anxiety sensitivity (Mason and Asmundson 2018). However, the RPE reported (13–15 RPE) was notably lower than recommended in previous literature (≥18; Mason and Asmundson 2018). We might expect that perceived exercise intensity may be more influential than actual exercise intensity to induce changes to anxiety sensitivity, as the perception of interoceptive cues resulting from the physiological state of the body is theorised to be instrumental in reducing physical anxiety sensitivity (Sabourin et al. 2015). As the recruited aerobic group had relatively elevated levels of anxiety sensitivity (mean ± sd: 40.9 ± 11.38) and had lower or similar levels of physical (in)activity compared to previous research (LeBouthillier and Asmundson 2015; Mason and Asmundson 2018), they may have felt greater worry towards the body sensations which arose during exercise, subsequently feeling less safe or in control while exercising. Indeed, across the aerobic exercise bout, participants' perceived control of body symptoms reduced. This may indicate that participants did not have the capacity to feel safe enough in the exercise experience to begin to reduce fear towards the exercise symptoms, something that may require repeated engagement. Finally, participants reported a balanced proportion of both associative and dissociative thought content (i.e. neither highly associative, nor dissociative) throughout both forms of exercise. This may indicate that participants were not consciously and deliberately appraising somatic cues throughout either intervention. Together, these results suggest that participants had limited opportunities to reappraise the somatic experience of exercise that is required to reduce their anxiety sensitivity.

There are several strengths and limitations of this study. The study is strengthened by specifically recruiting participants with subclinically elevated trait anxiety. The inclusion of the stretching comparison condition allows us to isolate the aerobic component of exercise, as well as control for potential social interaction, achievement experiences and some of the physical experiences which may be associated with exercise. However, we recognise that a non-exercise comparison group would make the study more comparable to previous literature in the area. Furthermore, the sample recruited (i.e. a relatively young group largely populated by university staff and students) limits the generalisability of the current findings. The physical activity measure used to determine eligibility for the study only asked how often someone exercised per week rather than the amount of weekly exercise performed. The participant was eligible if they exercised 0–1 times per week. However, it could still be possible to meet the PA guidelines and therefore be classed as 'active' with 1 day of exercise. Although this is a limitation, we also measured aerobic capacity directly, which indicated that, on average, our sample was of 'poor' fitness, substantiating the self-report data showing the sample was inactive. Lastly, there is a 10-min difference in total time spent exercising between the AER and STR groups. The extra 10-min in the AER group was to provide time to warm-up and cool-down to ensure participant safety, as the sample comprised an inactive population (Bushman 2024). We managed this difference by aligning the midpoint data to capture the middle of the active exercise portion of the aerobic condition, as well as ensuring participants knew when these periods of time were starting and ending so they could adjust their self-selected intensity as they wished.

Future research investigating the effect of chronic self-selected intensity aerobic exercise would be a valuable addition to this literature. Repeated bouts of exercise may be required to provide opportunities to build confidence, safety, and positive appraisal within the exercise setting, facilitating a reduction in anxiety sensitivity and further improvements to state anxiety. Ultimately, the results from this study suggest that both aerobic exercise of a self-selected intensity and static stretching reduce anxiety acutely, providing cost-effective and accessible strategies to improve psychological well-being within a moderately anxious, inactive population.


### Acknowledgments

Open access publishing facilitated by University of Otago, as part of the Wiley - University of Otago agreement via the Council of Australian University Librarians.

### Funding

This study was supported by RDK (Grant UOO1902).


### Conflicts of Interest

The authors declare no conflicts of interest.

### References


Abrantes, A. M., N. McLaughlin, B. D. Greenberg, et al. 2012. "Design and Rationale for a Randomized Controlled Trial Testing the Efficacy of Aerobic Exercise for Patients with Obsessive-Compulsive Disorder." *Mental Health and Physical Activity* 5, no. 2: 155–165.

Alblooshi, S., M. Taylor, and N. Gill. 2023. "Does Menopause Elevate the Risk for Developing Depression and Anxiety? Results from a Systematic Review." Australas Psychiatry 31, no. 2: 165–173.

Avancini, C., D. Marinazzo, D. Sanabria, J. J. Pérez-Díaz, J.-A. Salas-Montoro, and L. F. Ciria. 2025. "Investigating Cognitive-Physical Task Interaction during Self-Paced Cycling: A Granger Causality Study." *Psychology of Sport and Exercise* 78: 102809.

Baden, D. A., L. Warwick-Evans, and J. Lakomy. 2004. "Am I Nearly There? The Effect of Anticipated Running Distance on Perceived Exertion and Attentional Focus." *Journal of Sport and Exercise Psychology* 26, no. 2: 215–231.

Balke, B., and R. W. Ware. 1959. "An Experimental Study of Physical Fitness of Air Force Personnel." *United States Armed Forces Medical Journal* 10, no. 6: 675–688.

Besio, M. 2003. *The Effect of Static Stretching on Levels of Anxiety and Job Performance in a Corporate Population*. Hofstra University.

Bok, D., M. Rakovac, and C. Foster. 2022. "An Examination and Critique of Subjective Methods to Determine Exercise Intensity: The Talk Test, Feeling Scale, and Rating of Perceived Exertion." *Sports Medicine* 52, no. 9: 2085–2109.

Borg, G. 1970. “Perceived Exertion as an Indicator of Somatic Stress.” *Scandinavian Journal of Rehabilitation Medicine* 2, no. 2: 92–98.

Breus, M. J., and P. J. O’Connor. 1998. “Exercise-Induced Anxiolysis: A Test of the “Time Out” Hypothesis in High Anxious Females.” *Medicine & Science in Sports & Exercise* 30, no. 7: 1107–1112.

Broman-Fulks, J. J., K. Kelso, and L. Zawilinski. 2015. “Effects of a Single Bout of Aerobic Exercise versus Resistance Training on Cognitive Vulnerabilities for Anxiety Disorders.” *Cognitive Behaviour Therapy* 44, no. 4: 240–251.

Bushman, B. A. 2024. “The Value of Warm-up and Cool-Down.” *ACSM’s Health & Fitness Journal* 28, no. 2: 6–9.

Butki, B. D., D. L. Rudolph, and H. Jacobsen. 2001. “Self-Efficacy, State Anxiety, and Cortisol Responses to Treadmill Running.” *Perceptual and Motor Skills* 92, no. 3: 1129–1138.

Buttar, K. K., S. Kacker, and N. Saboo. 2022. “Normative Data of Maximal Oxygen Consumption (VO).” *Population* 13: 14.

Carter, M. M., N. W. Marin, and K. L. Murrell. 1999. “The Efficacy of Habituation in Decreasing Subjective Distress among High Anxiety-Sensitive College Students.” *Journal of Anxiety Disorders* 13, no. 6: 575–589.

Chen, M. J., X. Fan, and S. T. Moe. 2002. “Criterion-Related Validity of the Borg Ratings of Perceived Exertion Scale in Healthy Individuals: A Meta-Analysis.” *Journal of Sports Sciences* 20, no. 11: 873–899.

Connor, M., E. A. Hargreaves, O. K. Scanlon, and O. K. Harrison. 2023. “The Effect of Acute Exercise on State Anxiety: *A Systematic Review.*” *Sports* 11, no. 8: 145.

Cooper, S. L., and P. D. Tomporowski. 2017. “Acute Effects of Exercise on Attentional Bias in Low and High Anxious Young Adults.” *Mental Health and Physical Activity* 12: 62–72.

Cox, R. H., T. R. Thomas, P. S. Hinton, and O. M. Donahue. 2004. “Effects of Acute 60 and 80% $VO_2$max Bouts of Aerobic Exercise on State Anxiety of Women of Different Age Groups across Time.” *Research Quarterly for Exercise and Sport* 75, no. 2: 165–175.

Ekkekakis, P. 2003. “Pleasure and Displeasure from the Body: Perspectives from Exercise.” *Cognition and Emotion* 17, no. 2: 213–239.

Ekkekakis, P., E. A. Hargreaves, and G. Parfitt. 2013. “Invited Guest Editorial: Envisioning the Next Fifty Years of Research on the Exercise–affect Relationship.” *Psychology of Sport and Exercise* 14, no. 5: 751–758.

Ekkekakis, P., and E. Lind. 2006. “Exercise Does Not Feel the Same when You Are Overweight: The Impact of Self-Selected and Imposed Intensity on Affect and Exertion.” *International Journal of Obesity* 30, no. 4: 652–660.

Ekkekakis, P., G. Parfitt, and S. J. Petruzzello. 2011. “The Pleasure and Displeasure People Feel when They Exercise at Different Intensities: Decennial Update and Progress towards a Tripartite Rationale for Exercise Intensity Prescription.” *Sports Medicine* 41: 641–671.

Ensari, I., T. A. Greenlee, R. W. Motl, and S. J. Petruzzello. 2015. “Meta-Analysis of Acute Exercise Effects on State Anxiety: An Update of Randomized Controlled Trials over the past 25 Years.” *Depression and Anxiety* 32, no. 8: 624–634.

Every-Palmer, S., M. Jenkins, P. Gendall, et al. 2020. “Psychological Distress, Anxiety, Family Violence, Suicidality, and Wellbeing in New Zealand during the COVID-19 Lockdown: A Cross-Sectional Study.” *PLoS One* 15, no. 11: e0241658.

Faul, F., E. Erdfelder, A.-G. Lang, and A. Buchner. 2007. “G* Power 3: A Flexible Statistical Power Analysis Program for the Social, Behavioral, and Biomedical Sciences.” *Behavior Research Methods* 39, no. 2: 175–191.

Focht, B. C., and H. A. Hausenblas. 2001. “Influence of Quiet Rest and Acute Aerobic Exercise Performed in a Naturalistic Environment on Selected Psychological Responses.” *Journal of Sport and Exercise Psychology* 23, no. 2: 108–121.

Gaskill, S. E., B. C. Ruby, A. J. Walker, O. A. Sanchez, Serass R.C., and Leon A. S. 2001. “Validity and Reliability of Combining Three Methods to Determine Ventilatory Threshold.” *Medicine & Science in Sports & Exercise* 33, no. 11: 1841–1848.

Hamlyn-Williams, C. C., P. Freeman, and G. Parfitt. 2014. “Acute Affective Responses to Prescribed and Self-Selected Exercise Sessions in Adolescent Girls: An Observational Study.” *BMC Sports Science, Medicine and Rehabilitation* 6, no. 1: 1–9.

Hardy, C. J., and W. J. Rejeski. 1989. “Not What, but How One Feels: The Measurement of Affect during Exercise.” *Journal of Sport and Exercise Psychology* 11, no. 3: 304–317.

Herzog, E., M. Vos, V. Keller, S. Koch, K. Takano, and B. Cludius. 2022. “The Benefits of Physical Exercise on State Anxiety: Exploring Possible Mechanisms.” *Mental Health and Physical Activity* 23: 1–11.

Jones, L., and Z. Zenko. 2023. “A Systematic Narrative Review of Extrinsic Strategies to Improve Affective Responses to Exercise.” *Frontiers in Sports and Active Living* 5: 1186986.

Jung, M. E., J. E. Bourne, and J. P. Little. 2014. “Where Does HIT Fit? An Examination of the Affective Response to High-Intensity Intervals in Comparison to Continuous Moderate-and Continuous Vigorous-Intensity Exercise in the Exercise Intensity-Affect Continuum.” *PloS One* 9, no. 12: e114541.

Kemper, C. J., J. Lutz, T. Bähr, H. Rüddel, and M. Hock. 2012. “Construct Validity of the Anxiety Sensitivity Index–3 in Clinical Samples.” *Assessment* 19, no. 1: 89–100.

Knapen, J., E. Sommerijns, D. Vancampfort, et al. 2009. “State Anxiety and Subjective Well-Being Responses to Acute Bouts of Aerobic Exercise in Patients with Depressive and Anxiety Disorders.” *British Journal of Sports Medicine* 43, no. 10: 756–759.

Lakens, D. 2013. “Calculating and Reporting Effect Sizes to Facilitate Cumulative Science: A Practical Primer for t-Tests and ANOVAs.” *Frontiers in Psychology* 4: 863.

LeBouthillier, D. M., and G. J. Asmundson. 2015. “A Single Bout of Aerobic Exercise Reduces Anxiety Sensitivity but Not Intolerance of Uncertainty or Distress Tolerance: A Randomized Controlled Trial.” *Cognitive Behaviour Therapy* 44, no. 4: 252–263.

Mason, J. E., and G. J. Asmundson. 2018. “A Single Bout of Either Sprint Interval Training or Moderate Intensity Continuous Training Reduces Anxiety Sensitivity: A Randomized Controlled Trial.” *Mental Health and Physical Activity* 14: 103–112.

McLaughlin, K. A., and M. L. Hatzenbuehler. 2009. “Stressful Life Events, Anxiety Sensitivity, and Internalizing Symptoms in Adolescents.” *Journal of Abnormal Psychology* 118, no. 3: 659.

McWilliams, L. A., and G. J. Asmundson. 2001. “Is There a Negative Association between Anxiety Sensitivity and Arousal-Increasing Substances and Activities?” *Journal of Anxiety Disorders* 15, no. 3: 161–170.

Meier, N. F., and A. S. Welch. 2016. “Walking versus Biofeedback: A Comparison of Acute Interventions for Stressed Students.” *Anxiety, Stress, and Coping* 29, no. 5: 463–478.

Merikangas, K. R., He J-p, M. Burstein, et al. 2010. “Lifetime Prevalence of Mental Disorders in US Adolescents: Results from the National Comorbidity Survey Replication–Adolescent Supplement (NCS-A).” *Journal of the American Academy of Child & Adolescent Psychiatry* 49, no. 10: 980–989.

Metzger, R. L. 1976. “A Reliability and Validity Study of the State-Trait Anxiety Inventory.” *Journal of Clinical Psychology* 32, no. 2: 276–278.

Naragon-Gainey, K. 2010. “Meta-Analysis of the Relations of Anxiety Sensitivity to the Depressive and Anxiety Disorders.” *Psychological Bulletin* 136, no. 1: 128.

Olthuis, J. V., M. C. Watt, and S. H. Stewart. 2014. "Anxiety Sensitivity Index (ASI-3) Subscales Predict Unique Variance in Anxiety and Depressive Symptoms." *Journal of Anxiety Disorders* 28, no. 2: 115–124.

Petruzzello, S. J., D. M. Landers, B. D. Hatfield, K. A. Kubitz, and W. Salazar. 1991. "A Meta-Analysis on the Anxiety-Reducing Effects of Acute and Chronic Exercise." *Sports Medicine* 11, no. 3: 143–182.

Pine, D. S., P. Cohen, D. Gurley, J. Brook, and Y. Ma. 1998. "The Risk for Early-Adulthood Anxiety and Depressive Disorders in Adolescents with Anxiety and Depressive Disorders." *Archives of General Psychiatry* 55, no. 1: 56–64.

Ritchie, C. 2012. "Rating of Perceived Exertion (RPE)." *Journal of Physiotherapy* 58, no. 1: 62.

Robinson, L. J., and M. H. Freeston. 2014. "Emotion and Internal Experience in Obsessive Compulsive Disorder: Reviewing the Role of Alexithymia, Anxiety Sensitivity and Distress Tolerance." *Clinical Psychology Review* 34, no. 3: 256–271.

Roelands, B., J. de Koning, C. Foster, F. Hettinga, and R. Meeusen. 2013. "Neurophysiological Determinants of Theoretical Concepts and Mechanisms Involved in Pacing." *Sports Medicine* 43: 301–311.

Rose, E., and G. Parfitt. 2007. "A Quantitative Analysis and Qualitative Explanation of the Individual Differences in Affective Responses to Prescribed and Self-Selected Exercise Intensities." *Journal of Sport and Exercise Psychology* 29, no. 3: 281–309.

Rose, E., and G. Parfitt. 2012. "Exercise Experience Influences Affective and Motivational Outcomes of Prescribed and Self-Selected Intensity Exercise." *Scandinavian Journal of Medicine & Science in Sports* 22, no. 2: 265–277.

Sabourin, B. C., S. H. Stewart, M. C. Watt, and O. E. Krigolson. 2015. "Running as Interoceptive Exposure for Decreasing Anxiety Sensitivity: Replication and Extension." *Cognitive Behaviour Therapy* 44, no. 4: 264–274.

Skapinakis, P. 2014. "Spielberger State-Trait Anxiety Inventory." In *Encyclopedia of Quality of Life and Well-Being Research*, edited by A. C. Michalos, 6261–6264. Springer.

Spielberger, C., R. Goruch, R. Lushene, P. Vagg, and G. Jacobs. 1983. *Manual for the State-Trait Inventory STAI (form Y)*. Consulting Psychologists Press.

Szabo, A. 2003. "The Acute Effects of Humor and Exercise on Mood and Anxiety." *Journal of Leisure Research* 35, no. 2: 152–162.

Taylor, S., M. J. Zvolensky, B. J. Cox, et al. 2007. "Robust Dimensions of Anxiety Sensitivity: Development and Initial Validation of the Anxiety Sensitivity Index-3." *Psychological Assessment* 19, no. 2: 176.

Van Landuyt, L. M., P. Ekkekakis, E. E. Hall, and S. J. Petruzzello. 2000. "Throwing the Mountains into the Lakes: On the Perils of Nomothetic Conceptions of the Exercise-Affect Relationship." *Journal of Sport and Exercise Psychology* 22, no. 3: 208–234.

Vazou-Ekkekakis, S., and P. Ekkekakis. 2009. "Affective Consequences of Imposing the Intensity of Physical Activity: Does the Loss of Perceived Autonomy Matter." *Hellenic Journal of Psychology* 6, no. 2: 125–144.

Wallman-Jones, A., P. Perakakis, M. Tsakiris, and M. Schmidt. 2021. "Physical Activity and Interoceptive Processing: Theoretical Considerations for Future Research." *International Journal of Psychophysiology* 166: 38–49.

Warburton, D. E., V. K. Jamnik, S. S. Bredin, and N. Gledhill. 2011. "The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+)." *The Health & Fitness Journal of Canada* 4, no. 2: 3–17.

Williams, D. M. 2008. "Exercise, Affect, and Adherence: An Integrated Model and a Case for Self-paced Exercise." *Journal of Sport and Exercise Psychology* 30, no. 5: 471–496. https://pmc.ncbi.nlm.nih.gov/articles/PMC4222174/pdf/nihms-637992.pdf.

Zenko, Z., R. M. Kahn, C. J. Berman, J. C. Hutchinson, and L. Jones. 2020. "Do Exercisers Maximize Their Pleasure by Default? Using Prompts to Enhance the Affective Experience of Exercise." *Sport, Exercise, and Performance Psychology* 9, no. 3: 405.