Sprint interval training in young adult males with & without elevated worry

Matthew P. Herring¹,²,ᵃ, Tom P. Aird¹,²,ᵇ, Chloe Forte¹,²,ᵇ, Courtney Frengopoulosᶜ, Brian P. Carson¹,²

¹ Department of Physical Education and Sport Sciences, University of Limerick, Ireland
² Physical Activity for Health Research Cluster, Health Research Institute, University of Limerick, Ireland
ᶜ Graduate Entry Medical School, University of Limerick, Ireland

ARTICLE INFO

Keywords:
Sprint interval training
Wingate
Anxiety
Worry
Young adults
Generalized anxiety disorder

ABSTRACT

Using a pre-post design, we investigated state anxiety and worry responses to a single Wingate, three weeks of sprint interval training (SIT), and, change in response to a single Wingate. Differences between males with and without elevated worry were explored. Thirty-eight young adult males, 18 with elevated worry (Penn State Worry Questionnaire [PSWQ] ≥ 45), completed a single 30s Wingate at 7.5% body mass before and after three weeks of SIT (nine sessions of 4-6 sprints). The state subscale of the State-Trait Anxiety Inventory assessed state anxiety; the PSWQ measured worry and worry engagement. A single Wingate increased state anxiety (d = -0.37, [-0.82, 0.09]) and decreased worry engagement (d = 0.16, [-0.29, 0.61]). SIT resulted in non-significant reductions in state anxiety (d = 0.20, [-0.25, 0.65]) and worry (d = 0.09, [-0.36, 0.54]). SIT non-significantly attenuated state anxiety response to a single Wingate (d = 0.23, [-0.22, 0.68]), approximating a 2.5-fold reduction from pre- (d = -0.37, [-0.82, 0.09]) to post-SIT (d = -0.16, [-0.61, 0.29]). Improvements in worry (d = 0.61, [-0.04, 1.26]) and worry engagement (d = 0.60, [-0.05, 1.25]) were moderately larger among males with elevated worry. Findings indicated that a single Wingate may acutely perturb state anxiety and improve worry. Three weeks of SIT may improve anxiety and worry and response to a single Wingate. Responses were moderately larger among males with elevated worry.

1. Introduction

Evidence supports small-to-moderate anxiolytic effects of acute and chronic exercise among healthy adults (Conn, 2010; Ensari, Greenlee, Motl, & Petruzzello, 2015), chronically-ill adults (Herring, O’Connor, & Dishman, 2010), and some anxiety and/or stress-related disorder patients (Herring, Jacob, Suveg, Dishman, & O’Connor, 2012; Stubbs et al., 2017). Studies have largely focused on moderate-intensity aerobic exercise, but acute and chronic anxiolytic effects of other exercise modalities and exercise of varying intensities have been understudied. Recent evidence supported the anxiolytic effects of a single bout of vigorous-intensity exercise on state anxiety and worry among healthy young adults (McDowell, Campbell, & Herring, 2016), young adult females with worry indicative of analogue GAD (Herring, Hallgren, & Campbell, 2017), and young adult females and males with analogue GAD (Herring, Monroe, Gordon, & Campbell, 2019). However, the acute and chronic effects of sprint interval training (SIT) on state anxiety is understudied, and no study has investigated SIT effects on worry.

A scoping review of 42 articles involving 1258 participants highlighted the potential viability of interval exercise for psychological outcomes (Stork, Banfield, Gibala, & Martin Ginis, 2017). The review reinforced that most studies have focused on affect, enjoyment, exercise-related social-cognitive variables (e.g., self-efficacy), and perceptual responses (i.e., RPE), with clear methodological limitations across the evidence, including inconsistent terminology, measures, and interval protocols (Stork et al., 2017). Only one study of SIT reported findings for any anxiety-related outcome (Freese et al., 2014). Freese and colleagues (Freese et al., 2014) measured feelings of tension as a
secondary outcome and reported trivial reductions (ES = -0.17) following six weeks of SIT. However, the effects of a single sprint on anxiety remain understudied, and the effects of chronic SIT on anxiety and worry in adults with elevated worry indicative of probable GAD have not been explored.

Based on overlapping neuroanatomy (LeDoux, 2000; Vogt, 2005; Wiech & Tracey, 2009; Zhuo, 2008), it is plausible that anxiety responses to acute and chronic SIT mirror paradoxical findings for pain (Naugle, Fillingim, & Riley III, 2012; O’Connor & Cook, 1999), such that high intensity exercise may perturb anxiety, but repeated exposure to the same stimulus reduces both resting anxiety and response to the same acute stimulus. Exercise may serve as interoceptive exposure, repeatedly inducing feared sensations to ultimately reduce anxiety response over time (Asmundson et al., 2013; Craske, Barlow, & Meadows, 2000). Recently, anxiety sensitivity (i.e., fear of anxiety-related symptoms) was reduced following a single SIT session, supporting that SIT may serve as interoceptive exposure for anxiety-related constructs (Mason & Asmundson, 2018). However, anxiety responses were not reported, and whether chronic SIT changed resting levels of anxiety and acute response to a single sprint was not investigated.

Thus, the objectives of this study were to quantify: (aim 1) state anxiety and worry responses to a single Wingate; (aim 2) state anxiety and worry responses to three weeks of SIT; and, (aim 3) the extent to which three weeks of SIT changed acute responses to a single Wingate. An additional aim (aim 4) was to characterize/confirm the anticipated physiological adaptations to three weeks of SIT, including SIT peak power output, mean power output, and fatigue index. An exploratory aim (aim 5) was to explore responses among young adult males with and without elevated worry. The authors hypothesized that: (aim 1) a single sprint would acutely exacerbate state anxiety and worry; (aim 2) SIT would result in small-to-moderate reductions in state anxiety and worry; (aim 3) SIT would attenuate acute exacerbations in state anxiety and worry in response to a single sprint; (aim 4) SIT would significantly improve markers of physiological adaptation; and, (aim 5) the magnitude of response to SIT would be stronger among young males with elevated worry.

2. Methods

2.1. Participants & recruitment

This research protocol was approved by the University Research Ethics Committee and conforms to the Declaration of Helsinki. All participants provided written informed consent and completed a medical history screening questionnaire that included the Physical Activity Readiness Questionnaire prior to participation. Participants were recruited by word of mouth and through local advertisements, including emails to the student and staff body at the University of Limerick, with recruitment taking place from January–December 2018. Inclusion criteria were: (i) healthy non-obese (BMI < 30 kg m⁻²) males aged 18-35y; (ii) no medical contraindication to participate in exercise; and, (iii) maximal oxygen uptake (VO₂max) of < 50 ml.kg.min⁻¹. A single-group pre-post design was employed to assess potential changes in outcome measures from baseline to post-intervention. GAD status was not an inclusion/exclusion criterion; participants were classified after baseline testing to allow exploratory analyses. According to power analysis with G*Power, assuming a two-tail α = 0.05 and a correlation of r = 0.7 between repeated measures, 38 participants would provide >80% statistical power to detect a moderate (f = 0.18; d = 0.36) magnitude difference between baseline and post SIT pre-post sprint responses based on previous evidence of acute effects of vigorous exercise on anxiety-related outcomes (Herring et al., 2017, 2019; Mason & Asmundson, 2018; McDowell et al., 2016). Forty-two participants were recruited based on an expected attrition rate of <10% due to the healthy population recruited, the short study duration, and very low attrition in pilot testing. Four participants were excluded from analyses as they either did not meet inclusion criteria (VO₂max > 50 ml kg.min⁻¹; n = 1) or did not comply with the training protocol (n = 3). Data from the remaining 38 participants are presented herein.

2.2. Procedures

2.2.1. Baseline measures

Participants arrived to the lab after an overnight fast to complete VO₂max testing to assess eligibility, as this study aimed to recruit a homogeneous cohort of aerobically untrained participants. After recording height and weight, an incremental cycle ergometer test (SRM, Germany) was used to determine VO₂max via indirect calorimetry (Ultima™ CardiO²G, MGC diagnostics, USA). Participants completed a 5-min warm-up stage at 50W with subsequent 1-min incremental stages (30W) until volitional fatigue, or until participants could no longer maintain a cadence ≥80 revolutions per minute (rpm). RPE (Borg, 1982) and heart rate (Polar RS800 HR monitor, Kempele, Finland) were used as markers of exercise intensity after every second stage and at the end of each stage, respectively. Resting inspired and expired gas measurements were recorded for 1 min prior to and following completion of VO₂max testing. VO₂max was achieved if ≥2 of the following criteria were met: a sustained plateau or decline in VO₂ was observed; heart rate within 85% of age predicted max (220 – age); RPE ≥17; respiratory exchange ratio ≥1.10; or, participant indicated volitional exhaustion (Howley, Bassett, & Welch, 1995).

2.2.2. Pre-SIT measures

Approximately 48h later, participants attended the lab after a 2-h fast and having refrained from caffeine intake for 12 h. Upon arrival, participants completed a seven-day physical activity recall and state anxiety and worry were assessed with the state subscale (STAI-Y1) of the State-Trait Anxiety Inventory (Spielberger et al., 1983) and the Penn State Worry Questionnaire (PSWQ) (Meyer, Miller, Metzger, & Borkovec, 1990), respectively. Participants then completed a standardized 5-min warm-up on a cycle ergometer (Monark 894E, Sweden), consisting of unloaded cycling at 60–70 rpm followed by a 30s “all-out” Wingate pedalling against a resistance equivalent to 7.5% of body mass. Once a cadence of 120 rpm was reached, the resistance was automatically applied. Participants were instructed to pedal at maximal intensity with standardized encouragement from researchers. When 30s cycling had elapsed, resistance was removed, and a 3-min active recovery period followed. Physiological parameters for the 30s Wingate test were recorded, including peak power output, mean power output, and fatigue index. Participants then rested quietly for 10-min, and STAI-Y1 and PSWQ were completed.

2.2.3. SIT intervention

Between 2 and 5 days following completion of baseline measures, participants commenced the 3-week SIT intervention, comprised of nine SIT sessions completed with ~48 h rest between sessions. Each training session followed an overnight fast and abstinence from caffeine and alcohol for the previous 12 and 24 h, respectively. All training sessions were supervised by two members of the overall research team, and participants were provided with extensive verbal encouragement and instruction to exert maximal effort for each sprint bout. Participants refrained from completing any other forms of vigorous exercise for the duration of the SIT intervention. SIT consisted of 4–6 (four sprints in sessions 1–3, five sprints in sessions 4–6, six sprints in sessions 7–9), 30s “all-out” maximal cycle sprints on a cycle ergometer, pedalling at a resistance equivalent to 7.5% body mass. Four minutes active recovery followed each sprint. RPE was assessed following each sprint in each training session, and all participants reported RPE of 20 in all cases. Standardised 5-min warm-up and 3-min cool-down periods of unloaded cycling at 60–70 rpm preceded and followed each bout.
2.2.4. Post-SIT measures
Post-SIT testing was completed 72–96 h following the final SIT session. Procedures were identical to pre-SIT measures.

2.3. Outcome measures

2.3.1. State-Trait Anxiety Inventory (STAI-Y1)
State anxiety was measured with the 20-item STAI-Y1; total scores range from 20 to 80 (Spielberger et al., 1983). The psychometric properties of the STAI are well-established; internal consistency was adequate in the current sample (α = 0.70).

2.3.2. Penn State Worry Questionnaire (PSWQ)
Worry was assessed using the 16-item PSWQ; total scores range from 16 to 80 (Meyer et al., 1990). The psychometric properties of the PSWQ are well-established (Meyer et al., 1990). Scores have been shown to be sensitive to change in response to acute exercise (Herring et al., 2017; McDowell et al., 2016) and exercise training (Herring et al., 2012). Though there has been some controversy over the two-factor structure of the PSWQ (Brown, 2003), worry engagement (11 items worded in the direction of pathological worry) and absence of worry (five reverse-scored items to combat acquiescence) subscales can be calculated. However, the authors’ recent report questioned the psychometric properties and sensitivity to change of the absence of worry subscale, suggesting that worry engagement may be a more psychometrically sound and sensitive measure of exercise effects on worry when considered independent of absence of worry (Herring et al., 2017). Thus, results for worry engagement and total PSWQ were reported here. Internal consistency for these were adequate (α ≥ 0.70). Participants were classified with (n = 18) and without elevated worry (n = 20) based on PSWQ scores ≥45 (Behar, Alcaine, Zuellig, & Borkovec, 2003).

2.4. Statistical analyses
Data analyses were performed using SPSS 22.0. Missing data for worry (n = 1) and worry engagement (n = 1) were imputed such that time-variant responses for each variable were entered as predictors into separate multiple linear regression models and predicted values were retained. Paired samples t-tests quantified pre-training acute response to a single sprint (Aim 1) and training response (i.e., differences from baseline to post-training; Aim 2), as well as the physiological adaptations to SIT (Aim 4). The magnitude of change was quantified with Cohen’s d; effects were calculated such that pre-post improvements and exacerbations resulted in positive and negative effect sizes, respectively. Two session (pre-training/post-training) X two time (pre-sprint/post-sprint) repeated measures ANOVA examined differences between pre-training acute responses and post-training acute responses (Aim 3). Given increased calls to move beyond null-hypothesis significance testing in favor of effect sizes and confidence intervals (Cumming, 2013), the magnitude of change in pre- and post-training acute response were quantified and compared using Hedges’ d effect sizes and associated 95% confidence intervals; effect sizes were adjusted for small sample bias, and improved outcomes resulted in positive effect sizes (Hedges & Olkin, 1985). Effect sizes were appraised based on Cohen’s suggested thresholds, such that 0.2, 0.5, and 0.8 represented small, moderate, and large effects. Stratified analyses explored potential differential responses based on elevated worry status (Aim 5).

3. Results

3.1. Baseline characteristics
Table 1 presents baseline participant characteristics and outcomes. Normative VO2 max scores which have been characterized in similarly aged non-athletic populations indicate similar levels of cardiorespiratory fitness compared to this study cohort which have been previously characterized as “moderate” levels of cardiorespiratory fitness (Heyward, 1998; Kaminsky, Arena, & Myers, 2015).

3.2. Pre-training response to a single sprint (aim 1)

Table 2 presents descriptive statistics and effect sizes across sessions. At pre-training, state anxiety was significantly increased following a single sprint (t(17) = -3.00, p ≤ 0.005; d = -0.37, 95%CI [-0.82, 0.09]). Non-significant decreases were found for worry engagement (t(17) = 1.75, p ≥ 0.08; d = 0.16, [-0.29, 0.61]) and worry (t(17) = 1.00, p ≥ 0.33; d = 0.07, [-0.37, 0.52]).

3.3. Response to three weeks of sprint interval training (aim 2)

Table 3 presents outcome responses to training. No significant changes were found for state anxiety (t(17) = 1.37, p ≥ 0.17; d = 0.20, [-0.25, 0.65]), worry (t(17) = 0.74, p ≥ 0.46; d = 0.09, [-0.36, 0.54]), or worry engagement (t(17) = -0.06, p ≥ 0.95; d = -0.01, [-0.46, 0.44]).

3.4. Change in response to a single sprint following training (aim 3)

Non-significant Session X Time interactions were found for state anxiety (F(1,19) = 3.53, p ≥ 0.06; d = 0.23, [-0.22, 0.68]), worry (F(1,17) = 0.26, p ≥ 0.61; d = -0.06, [-0.51, 0.39]), and worry engagement (F(1,17) = 0.08, p ≥ 0.77; d = -0.05, [-0.50, 0.40]). Significant main effects for session (F(1,17) = 4.51, p < 0.05) and time (F(1,17) = 6.74, p < 0.02) were found for state anxiety. Compared to pre-training, post-Wingate state anxiety was significantly lower at post-training (mean difference: -3.34, p < 0.02), and post-Wingate state anxiety was significantly higher than pre-Wingate at pre-training (mean difference: 3.29, p ≤ 0.005). A significant main effect for time was found for worry engagement (F(1,17) = 5.22, p ≤ 0.03); compared to pre-Wingate, post-Wingate worry engagement was non-significantly lower at pre-training (mean difference: -1.16, p ≥ 0.08) and post-training (mean difference: -0.87, p ≥ 0.21).

3.5. Physiological responses to three weeks of SIT (aim 4)

Table 4 presents findings related to the physiological adaptations to three weeks of SIT, quantified by changes in Wingate peak power output, mean power output, and fatigue index. In the full sample, significant improvements from baseline were observed for Wingate peak power output (t(19) = 6.13, p < 0.001) and mean power output (t(19) = 6.37, p < 0.001), while fatigue index was unchanged from baseline (t(19) = -0.07, p ≥ 0.38).

3.6. Potential differential responses based on elevated worry (aim 5)

Prior to SIT, among males without elevated worry, state anxiety was significantly increased (t(19) = -2.39, p ≤ 0.03; d = -0.41, [-1.03, 0.22]), but there were no significant changes in worry (t(19) = -0.37, p ≥ 0.71; d = -0.04, [-0.66, 0.58]) or worry engagement (t(19) = 1.00, p ≥ 0.33; d = 0.13, [-0.49, 0.75]). Among males with elevated worry, no significant changes were found for state anxiety (t(19) = -1.85, p ≥ 0.08; d = -0.36, [-1.02, 0.30]), worry (t(19) = 1.45, p ≥ 0.16; d = 0.32, [-0.34, 0.97]), or worry engagement (t(19) = 1.42, p ≥ 0.17; d = 0.31, [-0.34, 0.97]). Following SIT, among males with elevated worry, non-significant reductions were found for state anxiety (t(19) = 1.47, p ≥ 0.16; d = 0.31, [-0.35, 0.96]), worry (t(19) = 1.54, p ≥ 0.14; d = 0.40, [-0.26, 1.06]), and worry engagement (t(19) = -1.18, p ≥ 0.25; d = 0.26, [-0.40, 0.91]). No significant changes were found for state anxiety (t(19) = 0.56, p ≥ 0.58; d = 0.14, [-0.48, 0.76]), worry (t(19) = -0.54, p ≥ 0.59; d = -0.11, [-0.73, 0.51]), or worry engagement (t(19) = -0.99, p ≥ 0.33; d = -0.22, [-0.84, 0.40]) among males without elevated worry. The
magnitude of difference in these changes between males with and without elevated worry was moderate for both worry (d = 0.61, [-0.04, 1.26]) and worry engagement (d = 0.60, [-0.05, 1.25]), and small for state anxiety (d = 0.19, [-0.45, 0.83]).

No significant Session x Time interactions were found for state anxiety (F(1,19) = 3.40, p = 0.08; d = 0.29, [-0.33, 0.92]), worry (F(1,19) = 0.01, p = 0.91; d = -0.01, [-0.51, 0.39]), or worry engagement (F(1,19) = 0.01, p = 0.94; d = 0, [-0.62, 0.62]) among males without elevated worry. Among males with elevated worry, Session x Time interactions for state anxiety (F(1,17) = 0.69, p = 0.41; d = 0.16, [-0.50, 0.81]), worry (F(1,17) = 0.25, p = 0.62; d = -0.16, [-0.82, 0.49]), and worry engagement (F(1,17) = 0.08, p = 0.78; d = -0.09, [-0.74, 0.56]) were not statistically significant. A significant main effect for time was found for worry engagement (F(1,17) = 5.50, p < 0.04); a single sprint non-significantly reduced worry engagement at pre-training (mean difference: -1.61, p ≥ 0.18) and post-training (mean difference: -1.06, p ≥ 0.39).

Regarding physiological adaptations, in males without elevated worry, peak power (t₁₀ = 2.99, p ≤ 0.006) and mean power (t₁₀ = 3.45, p ≤ 0.002) were significantly improved, but fatigue index was not significantly changed (t₁₇ = -0.34, p > 0.28). Similarly, in males with elevated worry, both peak power (t₁₀ = 4.95, p < 0.001) and mean power (t₁₀ = 5.12, p < 0.001) were significantly improved, but fatigue index was not significantly changed (t₁₇ = 0.76, p > 0.22). See Table 4.

4. Discussion
To the authors’ knowledge, this is the first investigation to assess anxiety and worry responses to acute and chronic SIT. Among healthy young adult males, significant improvements in Wingate peak power and mean power outputs were observed, supporting adherence to the maintenance of maximal effort throughout the training intervention, which elicited physiological adaptations. A single Wingate significantly increased state anxiety and non-significantly decreased worry engagement prior to SIT; three weeks of SIT resulted in non-significant small magnitude reductions in state anxiety and worry; and, SIT resulted in a small attenuation of state anxiety response to a single Wingate. Transparently, these findings should be interpreted with some caution given the lack of a control condition. Exploratory analyses showed that state anxiety responses were consistent among males with and without elevated worry, but, compared to males without elevated worry, acute and chronic improvements in worry and worry engagement were moderately larger among males with elevated worry, including a potentially meaningful (Norman, Sloan, & Wyrwich, 2003) 0.40 (−0.26, 1.06) standard deviation improvement in worry following three weeks of SIT.

State anxiety was significantly increased at pre-training (d = -0.37, [-0.82, 0.09]) but not at post-training (d = -0.16, [-0.61, 0.29]), approximating a 2.5-fold reduction in the magnitude of state anxiety response following SIT. The small increase in state anxiety following a
Table 3
Outcome responses to three weeks of sprint interval training.

<table>
<thead>
<tr>
<th>Training Response</th>
<th>Without Elevated Worry (n = 20)</th>
<th>With Elevated Worry (n = 18)</th>
<th>Total Sample (n = 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post-SIT</td>
<td>Cohen’s d (95%CI)</td>
</tr>
<tr>
<td>Worry (PSWQ)</td>
<td>35.8 ± 7.4</td>
<td>36.7 ± 9.1</td>
<td>−0.11 (−0.73, 0.51)</td>
</tr>
<tr>
<td>Worry Engagement</td>
<td>21.1 ± 5.2</td>
<td>22.5 ± 7.5</td>
<td>−0.22 (−0.84, 0.40)</td>
</tr>
<tr>
<td>State Anxiety (STAI-Y1)</td>
<td>29.9 ± 6.5</td>
<td>28.9 ± 8.1</td>
<td>0.14 (−0.48, 0.76)</td>
</tr>
</tbody>
</table>

Abbreviations: STAI-Y1: State Subscale of the State-Trait Anxiety Inventory; PSWQ: Penn State Worry Questionnaire; Cohen’s d (95%CI) represent magnitude of change pre-post training within each group and in the overall sample; Hedges’ d (95%CI) represent comparison of Elevated Worry and Without Elevated Worry groups.

Table 4
Physiological responses to three weeks of sprint interval training.

<table>
<thead>
<tr>
<th>Training Response</th>
<th>Without Elevated Worry (n = 20)</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post-SIT</td>
<td>Cohen’s d (95%CI)</td>
</tr>
<tr>
<td>Wingate Peak Power Output (W.kg⁻¹)</td>
<td>11.6 ± 1.7</td>
<td>12.5 ± 2.1*</td>
<td>0.47 (−0.16, 1.10)</td>
</tr>
<tr>
<td>Wingate Mean Power Output (W.kg⁻¹)</td>
<td>8.0 ± 0.7</td>
<td>8.3 ± 0.8*</td>
<td>0.40 (−0.23, 1.03)</td>
</tr>
<tr>
<td>Wingate Fatigue Index (%)</td>
<td>59.7 ± 6.2</td>
<td>59.6 ± 9.7</td>
<td>−0.01 (−0.63, 0.61)</td>
</tr>
</tbody>
</table>

* indicates P < 0.01 vs. baseline; ** indicates P < 0.001 vs. baseline.
The small-to-moderate reductions in worry engagement and total worry following a single sprint found among males with elevated worry are consistent with recent reports of the effects of acute vigorous-intensity treadmill running among otherwise healthy young adult males (McDowell et al., 2016) and young adults males with analogue GAD (Herring et al., 2017, 2019). Scores for worry and worry engagement reported here among males were similar to or lower than previous reports among healthy young adult males (McDowell et al., 2016) and young adult males with analogue GAD (Herring et al., 2019). However, the small-to-moderate reductions in worry (d = 0.32, [-0.34, 0.97]) and worry engagement (d = 0.41, [-0.35, 0.97]) found following a single sprint among males with elevated worry are larger than the previously reported effects of 30-min of vigorous-intensity treadmill running on worry among young adult males with analogue GAD (d = 0.07) (Herring et al., 2019). These findings are potentially important in that, if a single bout of sprint exercise may time-efficiently yield even small improvements in worry among individuals with relatively favorable worry levels, the expected magnitude of improvement among individuals with significantly elevated worry, like those with GAD, may be larger. This remains untested and requires future investigation among individuals with clinically-diagnosed GAD.

Differential state anxiety and worry responses to a single high-intensity sprint may plausibly result from different mechanisms that underlie state anxiety responses versus worry responses. High-intensity sprints have been shown to change hemodynamic and oxygenation responses in the prefrontal cortex (Monroe et al., 2016), a region critical to worry and impaired emotional and attentional processing in GAD (Telzer et al., 2008; Via et al., 2019). Differences in state anxiety and worry responses to a single sprint may also have resulted from the measurement of primarily somatic anxiety responses by the STAI-Y1 (Spielberger et al., 1983) versus the measurement of primarily cognitive thoughts of worry by the PSWQ (Meyer et al., 1990).

Importantly, the 0.40 and 0.26 standard deviation improvements in worry and worry engagement, respectively, following SIT among males with increased worry are comparable to or larger than previously reported acute and chronic effects of aerobic and resistance exercise on worry among young adults with analogue and clinical levels of GAD (Herring et al., 2012, 2017, 2019). Based on the suggested minimal important difference of ½ standard deviation (Norman et al., 2003), the 0.40 (0.26, 1.06) standard deviation improvement in worry among males with elevated worry may represent a meaningful finding. This finding warrants future investigation such that the same SIT intervention is implemented among young adult males with clinically-diagnosed GAD. The hypothesized paradoxical findings for state anxiety response to a single sprint were supported. Prior to SIT, a single Wingate significantly increased state anxiety, potentially due to the relevant and anticipated increases in somatic symptoms that frequently accompany anxiety (i.e., elevated heart rate, respiration, perspiration, skin conductance). Importantly, though SIT did not elicit a statistically significant reduction in state anxiety, SIT attenuated the acute state anxiety response. This small magnitude attenuation of state anxiety response to a single Wingate is consistent with the cross-stressor adaptation and interoceptive exposure hypotheses; even a single bout of very high-intensity exercise may serve as both a stressor and as interoceptive exposure to ultimately reduce anxiety response to other stressors (Asmundson et al., 2013; Craske et al., 2000; Sothmann, 2006). State anxiety response to the same high-intensity sprint stimulus that acutely perturbed state anxiety was attenuated following repeated exposure to this same stressor across three weeks of SIT. These results are comparable to previous reports of increased and/or delayed post-exposure to this same stressor across three weeks of SIT. These results are comparable to previous reports of increased and/or delayed post-exposure to this same stressor across three weeks of SIT.
Declaration of competing interest

All authors have no conflicts of interest.

Acknowledgements

None.

References


Brown, T. A. (2003). Con...