THE EFFECT OF EXERCISE ON ANXIETY

THE EFFECTS OF MODERATE INTENSITY AEROBIC EXERCISE ON GENERAL AND STATE ANXIETY IN YOUNG ADULTS

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A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree Master of Science

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MASTER OF SCIENCE (2018) (Kinesiology) McMaster University Hamilton, Ontario McMaster University Hamilton, Ontario

TITLE: The effects of moderate intensity aerobic exercise on general and state anxiety in young adults.

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NUMBER OF PAGES: x, 49

ABSTRACT

Anxiety disorders are highly debilitating mental illnesses. They are characterized by heightened worry, physiological arousal, and avoidance behaviours that manifest as psychological, physiological, and behavioral disturbances (American Psychiatric Association, 2013; Kessler, Petukhova, Sampson, Zaslavsky, & Wittchen, 2012). Critically, a large proportion of the population suffers from elevated anxiety symptoms. Physical exercise has been proposed as a potential treatment for managing anxiety symptoms. The present study examined the effect of moderate intensity aerobic exercise training on both general and state anxiety symptoms in young adults. We hypothesized that general anxiety would be significantly lower after nine weeks of aerobic exercise training compared to no exercise training. We also hypothesized that a single bout of exercise would reduce state anxiety, and this reduction would be augmented with training. Fifty-five inactive participants (47 females, 85%) age 18 to 24 ($M \pm SD = 19.29 \pm 1.37$ years) were randomized into one of two groups: 1) exercise group, or 2) non-exercise control group. The exercise group completed three moderate intensity continuous aerobic exercise sessions per week for nine weeks, whereas the control group were asked to remain inactive. General anxiety was measured before and after the intervention using the Beck Anxiety Inventory, while state anxiety was measured twice a week using the short-form of the state scale of Spielberger State-Trait Anxiety Inventory. There was a significant interaction between group and baseline anxiety severity (p = .041) when controlling for aerobic fitness. Further exploration of this interaction revealed that the effect of aerobic exercise on post-intervention general anxiety was moderated by baseline anxiety severity [B = -9.84, p = .041, CI = -19.23 to -0.44]. Only the exercise subgroup with functionally-relevant baseline anxiety had lower post-intervention anxiety than the control group [B = -10.66, p = .0033, CI = -17.60 to -3.73]. Furthermore, an

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acute bout of exercise reduced state anxiety relative to the control group, but the effect did not emerge until weeks 4 to 6 of training (p < .001). Neither anxiety outcome was associated with changes in aerobic fitness, suggesting that some other aspect of the exercise program may have caused the benefits on anxiety. Collectively, these findings point to regular aerobic exercise as an effective tool for young adults to manage anxiety.

ACKNOWLEDGEMENTS

Firstly, I would like to thank my committee. To my supervisor, Dr. Jennifer Heisz, thank you for the opportunity to complete my Master's in the NeuroFit lab. Your never-ending support and guidance throughout this process has made me a more confident and well-rounded academic. I have learned so much throughout my time in my Master's, thank you for always giving us opportunities to grow and learn. Thank you to Dr. Michele Laliberte, for giving me the chance to learn about a field that has resonated with me more than a subject ever has. Thank you to Dr. Steven Bray, for always leading by example, and for your feedback and encouragement throughout this project.

Next, thank you to the members of the NeuroFit lab. I was so fortunate to work alongside an amazing undergraduate team throughout my two years. I sincerely enjoyed learning, laughing, and worrying about VO₂peak tests with each and every one of you. To the graduate students, thank you for helping to create a lab environment that was productive, supportive, and fun. To Dr. Barbara Fenesi, thank you for being the first person to show me the joys of academia, and for your countless lessons and pieces of advice. To Michelle, my partner in crime for the last 6 years, working alongside you has made me a better researcher and human being. To the officemate who made every day an adventure, Sheereen I cannot imagine this experience without you. To the rest of the McMaster Kinesiology Graduate Body, this community is one I will sincerely miss. Thank you for everything.

Thank you to my incredible family and friends outside of McMaster University. I have been blessed to be surrounded by individuals who always push me to pursue my goals, but never let me lose sight of the bigger picture. Thank you for all of your sacrifices. You are the people who respond to my stress, insecurities and loss with support and encouragement, and I am extremely grateful. I am certain that without this group of individuals, I would not be where I am today.

Lastly, thank you to the person who never stopped believing in me. Dad, my words on this page cannot capture how much you are missed.

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LIST OF ABBREVIATIONS

ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
BAI	Beck Anxiety Inventory
CBT	Cognitive behavioural therapy
HR	Heart rate
HPA axis	Hypothalamic-pituitary-adrenal axis
RPE	Rating of perceived exertion
STAI-6	6-item short form state scale of the State Trait Anxiety Inventory
SD	Standard deviation
SE	Standard error

DECLARATION OF ACADMIC ACHIEVEMENT

K.M. Lucibello's Role:

- Contributed to study concept, design, and material selection
- Submitted ethics amendment
- Primary on participant recruitment
- Trained and supervised students who assisted with data collection
- Primary on data collection, analysis and interpretation

Role of JJH:

- Obtained study funding
- Assisted with ethics amendment
- Contributed to study concept, design and material selection
- Contributed to data analysis and interpretation

INTRODUCTION

Overview

Anxiety disorders are highly debilitating mental illnesses that manifest as psychological, physiological, and behavioral disturbances (American Psychiatric Association, 2013; Kessler et al., 2012; Mendlowicz & Stein, 2000). Critically, a large proportion of the population suffers from anxiety symptoms. Exercise has been proposed as an alternative or concurrent treatment approach to traditional interventions for managing anxiety symptoms. The present study examined the effect of aerobic exercise training on both general and state anxiety symptoms in young adults. This research aims to understand the importance of regular exercise engagement for both acute and long-term anxiety symptom management.

In this introduction, I provide an overview of: 1) the prevalence and burden of anxiety in the general population, 2) the current treatments of anxiety disorders, 3) the cross-sectional relationship between aerobic exercise and anxiety, and 4) the efficacy of exercise as a treatment for anxiety symptoms in a variety of populations.

Anxiety prevalence and impact

Anxiety disorders are the most prevalent mental illness in Western societies (Kessler et al., 2009), with recent estimates suggesting a point prevalence of 10.4% (Baxter, Scott, Vos, & Whiteford, 2013) and a lifetime prevalence of 31.6% (Kessler et al., 2012). Collectively, anxiety disorders involve experiencing disproportionate fear and apprehension, along with associated physiological changes and behavioral disturbances in response to an actual or perceived threat (American Psychiatric Association, 2013). Anxiety disorders can emerge as early as adolescence (Lijster et al., 2017), and are approximately twice as common in females than males (McLean, Asnaani, Litz, & Hofmann, 2011). As categorized in the *Diagnostic Statistical Manual, 5th*

Edition, some of the most common anxiety disorders in adults include generalized anxiety disorder, social anxiety disorder, specific phobia, agoraphobia and panic disorder (American Psychiatric Association, 2013; Kessler et al., 2012). Anxiety disorders are chronic in nature, and are typically associated with low sustained recovery rates and a high probability of relapse (Bruce et al., 2005).

Anxiety disorders have a tremendous impact on both mental and physical health. Seventy-five percent of individuals who have had an anxiety disorder in their lifetime will also suffer from at least one other mental illness (Michael, Zetsche, & Margraf, 2007). Individuals diagnosed with an anxiety disorder are also more likely to suffer from a variety of chronic physical illnesses, including thyroid, respiratory, gastrointestinal and cardiovascular diseases, migraines, allergies and arthritis (Celano, Daunis, Lokko, Campbell, & Huffman, 2016; Sareen et al., 2006). These physical illnesses can further exacerbate an individual's psychological distress to compromise their quality of life (Mendlowicz & Stein, 2000).

Importantly, anxiety symptoms that are not high enough to meet the diagnostic criteria for an anxiety disorder can still pose a serious threat to mental health and overall quality of life. This is referred to as a subthreshold anxiety disorder. Individuals with subthreshold anxiety have similar characteristics as individuals with anxiety disorders with respect of age of symptom onset, persistence, comorbidity rate, distress and impaired functioning (Haller, Cramer, Lauche, Gass, & Dobos, 2014; Rucci et al., 2003). Furthermore, the presence of subthreshold anxiety often precedes the onset of an anxiety disorder within two years (Karsten et al., 2011). Critically, there are nearly twice as many individuals with subthreshold anxiety than anxiety disorders in both primary care settings and the general population (Balázs et al., 2013; Haller et al., 2014). Furthermore, compared to healthy individuals, individuals with subthreshold anxiety are also

greater consumers of healthcare (Bystritsky et al., 2010), and are at greater risk of developing comorbid physical conditions and early mortality (McCarron, Gunnell, Harrison, Okasha, & Smith, 2003; Roest, Martens, de Jonge, & Denollet, 2010). Therefore, targeting subthreshold anxiety symptoms in addition to clinical anxiety is important not only for alleviating distress and impaired functioning, but also for preventing the worsening of subthreshold anxiety symptoms into a clinical disorder. Henceforth, to indicate anxiety severity I will use the term *functionallyrelevant anxiety* to characterize individuals with either subthreshold or clinical anxiety (whose symptoms negatively impact their functioning) and *minimal anxiety* to characterize individuals whose symptoms are below this criteria and likely not interfering with functioning.

Efficacy of current medical treatments for anxiety

The two most common treatment approaches for anxiety disorders are prescription medications and cognitive behavioural therapy (CBT). The most frequently prescribed medications for anxiety disorders are serotonin-norepinephrine reuptake inhibitors and selective serotonin reuptake inhibitors (Ravindran & Stein, 2010). Both medications block the reuptake of their respective targeted neurotransmitter, leaving more norepinephrine or serotonin available in the synapse for transmission; this can regulate the abnormal functioning within the hippocampus, amygdala, and prefrontal cortex that is observed in anxiety disorders (Krishnan & Nestler, 2008; Ressler & Mayberg, 2007). In addition, these medications reduce stress responsivity by regulating the hypothalamic-pituitary-adrenal (HPA) axis response in individuals with generalized anxiety disorder (Lenze et al., 2011; Perlis, Fijal, Dharia, & Houston, 2013). While these medications are considered efficacious in the treatment of anxiety disorders for some individuals, a wide range of side effects (including headaches, fatigue, weight gain, insomnia and

sexual dysfunction) and a substantial proportion of non or partial responders have made their prescription controversial (Ballenger, 2004; Farach et al., 2012; Santarsieri & Schwartz, 2015).

CBT is an alternative treatment that aims to improve anxiety by identifying and correcting maladaptive cognitive processes that maintain the disorder, as well as teaching behavioral skills, such as exposure training and relaxation techniques, to manage and prevent symptoms (Beck & Emery, 2005). Meta-analyses have confirmed that CBT can successfully treat anxiety disorders (Carpenter et al., 2018; Hofmann & Smits, 2012). However, access to this type of treatment can be expensive, and wait times are lengthy given increasing demand for such services and a lack of appropriate funding (Gunter & Whittal, 2010; Mowbray et al., 2006).

There is also preliminary evidence to support the combination of pharmaceutical and psychological treatments for patients suffering from panic disorder, generalized anxiety disorder, and social phobia (Bandelow et al., 2015). However, there is some evidence that the combination of these treatments is not superior to either treatment alone (Crits-Christoph et al., 2011; Simon et al., 2008).

Despite these available treatments, less than half of the individuals who meet the criteria for an anxiety disorder actually seek mental health services, and only a third of this subgroup receive adequate pharmacological or psychological treatment (Wang et al., 2005). Furthermore, prescribed pharmacological and CBT treatment options are only available for those who meet the diagnostic criteria for an anxiety disorder, excluding the large proportion of individuals with subthreshold anxiety from these treatment opportunities. Collectively, these findings suggest that the majority of individuals suffering from *functionally-relevant anxiety* are not receiving sufficient treatment, highlighting the need for alternative or concurrent treatment options.

Cross-sectional relationships between anxiety and exercise

A growing body of literature supports the use of physical exercise as an accessible and inexpensive intervention for managing anxiety symptoms. Individuals who do not engage in any exercise are twice as likely to exhibit anxiety symptoms compared to those who engage in regular exercise (De Mello et al., 2013), and inactive individuals with panic disorder have worse symptoms than their active counterparts (Smits & Zvolensky, 2006). Regular exercise is associated with a decreased likelihood of satisfying the criteria for an anxiety disorder, even when controlling for sociodemographic variables and comorbid physical conditions (Goodwin, 2003). Moreover, ceasing regular exercise for as little as seven days results in significant increases in anxiety symptoms (Edwards & Loprinzi, 2016). Despite these benefits, a large proportion of individuals with an anxiety disorder are not exercising at the recommended moderate-to-vigorous intensity for 150 minutes each week (Helgadóttir, Forsell, & Ekblom, 2015; Tremblay et al., 2011). Therefore, examining a lighter duration and intensity of weekly aerobic exercise may be more practical and manageable for preliminary reductions in anxiety symptoms.

Quantifying anxiety change in exercise-intervention research.

Anxiety can be operationalized and measured in a variety of ways. Firstly, a retrospective assessment of accrued anxiety symptoms over a longitudinal period is an indication of *general anxiety*, which captures the degree to which different anxiety symptoms were present and burdensome over a prolonged period of time (Beck, 1988). Secondly, a singular assessment of anxiety in one particular moment is referred to as *state anxiety*: the transient activation of the autonomic nervous system and concurrent manifestation of subjective feelings of worry and apprehension (Spielberger, 1983). When simultaneously assessed, levels of general and state anxiety are positively correlated in healthy adults, clinically-anxious adults, and adults with a

different mental illness, suggesting the two constructs are related (Creamer, Foran, & Bell, 1995; Kabacoff, Segal, Hersen, & Van Hasselt, 1997; Steinglass et al., 2010). Critically, given the different time frames encompassed by each anxiety assessment, exercise researchers have typically employed only one of these two discrete methodologies for examining the anxiolytic effects of exercise.

Anxiolytic effects of exercise

Exercise training

Changes in general anxiety are often measured by comparing scores from before and after a longitudinal exercise intervention. While aerobic exercise training interventions typically demonstrate significant reductions in general anxiety, the size of the effect varies depending on the population being studied. For example, in healthy adults, exercise interventions have a significant but small effect on anxiety, with the largest of these effects elicited by moderate-tovigorous intensity aerobic protocols (Conn, 2010). However, moderate effects have been found in populations with elevated anxiety from conditions of chronic stress (Herring, O'Connor, & Dishman, 2010; Long & Van Stavel, 1995), such as adults with intellectual disabilities (Carraro & Gobbi, 2012) and clinically diagnosed anxiety (Stubbs et al., 2017). One of the first studies to demonstrate this found that twelve weeks of outdoor aerobic training decreased anxiety and panic symptoms in individuals with moderate-to-severe panic disorder compared to a placebo medication control group (Broocks et al., 1998). More recent evidence replicates this finding but also notes that the positive effect of exercise on anxiety symptoms is smaller than that of CBT (Hovland et al., 2013). Collectively, these studies suggest that the severity of general anxiety symptoms at intervention onset may moderate the effect of exercise, such that individuals who

are experiencing higher levels of general anxiety may be more responsive to the adaptations that occur during an exercise intervention.

Acute exercise

Acute changes in *state anxiety* are typically measured before and after a single bout of aerobic exercise. Multiple meta-analyses report a significant but small effect of a single bout of aerobic exercise on state anxiety, with the majority of studies only including adults with low levels of general anxiety (Ensari, Greenlee, Motl, & Petruzzello, 2015; Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991). Preliminary evidence suggests a larger effect of moderate intensity exercise on state anxiety in females with subthreshold anxiety (Herring, Hallgren, & Campbell, 2017), and this effect can be observed regardless of whether the exercise intensity was prescribed or self-selected (Knapen et al., 2009). However, there is a need for further evidence to inform whether anxiety severity influences acute state anxiety reductions following exercise.

Training effects on state anxiety

Reduction in state anxiety following an acute exercise bout may depend on the individual's fitness levels. Despite comparable state anxiety prior to the acute bout, larger reductions in state anxiety have been found in high fit individuals compared to low fit individuals following either a moderate (Dishman, Farquhar, & Cureton, 1994; Hoffman & Hoffman, 2008) or vigorous (Boutcher & Landers, 1988; Hallgren, Moss, & Gastin, 2010) bout of aerobic exercise. It follows that regular engagement in exercise may enhance the relief of state anxiety induced by an acute exercise bout. However, to our knowledge, only one study has examined the effect of exercise training on the acute state anxiety response in healthy young adults. In this study, similar state anxiety reductions were observed in response to a single moderate aerobic exercise bout during weeks one and eight of a training intervention (Hale and

Raglin, 2002). However, this study did not control for baseline fitness levels prior to the intervention. Given the potential relationship between fitness and the magnitude of the state anxiety response to exercise (Hallgren et al., 2010; Hoffman & Hoffman, 2008), this may be an important confound. Specifically, if higher fit individuals were recruited for the study a potential training effect may have already been present at week one. Therefore, to capture potential changes in state anxiety over the course of an intervention, it would be critical to selectively recruit participants with low levels of aerobic fitness and control for any individual differences in baseline fitness. Then, we could examine the effects of exercise training on the acute state anxiety response. Moderate intensity exercise has more consistently shown reductions in both general and state anxiety relative to more vigorous exercise (Martinez et al., 2015; Paolucci, Loukov, Bowdish & Heisz, 2018; Stubbs et al., 2017; Vancampfort et al., 2011; Wipfli et al., 2008). Therefore, we employed a moderate intensity protocol to examine these changes concurrently over time.

The purpose of the present study was to investigate the effect of a moderate intensity aerobic exercise intervention on anxiety in inactive young adults, controlling for baseline aerobic fitness. More specifically, the study aims: 1) to measure *general anxiety* after nine weeks of training, and 2) to determine whether *state anxiety* reductions from an acute bout of exercise change over the course of exercise training. The exercise group performed nine weeks of moderate intensity continuous stationary cycling, while the non-exercise control group was instructed to remain inactive throughout the duration of the study. For general anxiety, we hypothesized it would be lower in the exercise group than the control group following training. A secondary exploratory hypothesis was that anxiety severity at baseline would moderate the effect of aerobic exercise on post-intervention general anxiety. For state anxiety, we hypothesized that

it would reduce following an acute bout of exercise, and this reduction would be augmented with training.

METHODS

Participants

A sample size estimate was calculated using G*Power software (Version 3.1; www.gpower.hhu.de), based on Paolucci, Loukov, Bowdish & Heisz (2018)'s effect size for general anxiety change following aerobic exercise training (Cohen's d = .90). According to G*Power, 58 participants were required for the primary analysis using a four condition, repeated measures, within-between interaction design with one covariate and $\beta = 0.80$ and $\alpha = .05$. McMaster University students were recruited through physical poster and online advertisements. Inclusion criteria included being 18-30 years old, enrolled as a full-time student, and selfreportedly engaging in less than one hour of moderate-to-vigorous physical exercise per week outside of activities of daily living for the last six months. Sixty-seven participants were recruited and provided written informed consent. Of these participants, three dropped out prior to random assignment (lack of time = 1; personal issues = 2), seven dropped out following the beginning of the intervention (health = 1; lack of time = 2; personal issues = 1; undisclosed = 2; wanted to be more physically active = 2), and 55 completed the entire study. Following study completion, participants were compensated \$125 for their involvement. Hamilton Integrated Research Ethics Board approved the study protocols.

Materials

Anxiety

General Anxiety

The Beck Anxiety Inventory (BAI) is a 21-item questionnaire that was used to assess general anxiety (see Appendix). Participants rated how much they have been bothered by each specific symptom on a 4-point scale ranging from 0 (not at all) to 3 (severely) in the last seven days, and the responses were then summed to obtain a total score (Beck, Brown, Epstein, & Steer, 1988). Total score interpretation includes minimal (0-7), mild (8-15), moderate (16-25) and severe (26-63) general anxiety (Beck & Steer, 1993). The validity and reliability of the BAI has been confirmed in non-clinical university student samples (Borden, Peterson, & Jackson, 1991; Creamer et al., 1995). BAI scores positively and significantly correlate with clinicianadministered assessments of many different anxiety disorders, and a score of 11 or higher on the BAI has been found to be indicative of at least subthreshold anxiety symptoms (Karsten et al., 2011).

State Anxiety

The short-form of the state scale of Spielberger State-Trait Anxiety Inventory (STAI-6) is a six-item questionnaire that was used to assess state anxiety (see Appendix). Participants rated the degree to which each statement reflected how they were feeling in the moment on a 4-point scale ranging from 1 (not at all) to 4 (very much) (Marteau & Bekker, 1992). Items 1, 4, and 5 were reverse scored, and then the six items were summed to produce a total score, where a higher score is indicative of higher state anxiety (Marteau & Bekker, 1992). The STAI-6 produces comparable scores to the commonly utilized 20-item state subscale of the State-Trait Anxiety Inventory (Spielberger, 1983), but the minimal length makes it ideal for frequent administration. The STAI-6 has acceptable internal reliability (reliability coefficient = .82) and validity, and captures acute anxiety fluctuations in individuals experiencing low or high levels of state anxiety (Marteau & Bekker, 1992).

Aerobic fitness

Fitness was measured using a peak aerobic fitness assessment (VO₂peak) on a digital cycle ergometer (Lode Groningen, The Netherlands). The protocol begins with a 30 second warm up at 50 watts (W), followed by an incremental increase of 1W every two seconds. Participants were instructed to sustain a cadence between 80 and 100 revolutions per minute. Heart rate (HR) was continuously monitored using a *Polar* heart rate monitor, and expired gases were continuously monitored using a metabolic cart (MEDISOFT ExpAir Software VO2 System; Dinant, Belgium). Verbal encouragement was provided throughout the assessment, and the assessment was terminated once volitional exhaustion was reached. VO₂peak score (ml/min/kg), peak wattage (W) and heart rate (HR; beats/minute) were recorded upon volitional exhaustion. In addition to aerobic fitness, peak wattage and HR achieved during the baseline assessment were utilized to calculate personalized, moderate intensity ranges (40% peak W and 65-75% peak HR) for the exercise sessions (Garber et al., 2011; Paolucci, Loukov, Bowdish, & Heisz, 2018).

Rating of Perceived Exertion

The Borg Rating of Perceived Exertion (RPE) Scale is a 15-item scale that was used to assess how heavy or strenuous the cycling in an exercise session felt (See Appendix). Exercisers rated their perceived exertion on a scale from 6 (no exertion at all) to 20 (maximal exertion) (Borg, 1982). The reliability and validity of this scale has been confirmed in young, inactive individuals (Borg, 1998), with an RPE of 12-13 considered to be reflective of moderate intensity aerobic exercise (Garber et al., 2011).

Procedure

Overview

Prior to randomization, participants underwent baseline general anxiety, state anxiety, and aerobic fitness testing during two separate testing sessions. Following the completion of all baseline assessments, participants were stratified by sex and randomized into either a moderate intensity exercise condition (n = 27, 24 females) or a non-exercise control condition (n = 28, 23 females) for nine weeks (see Table 1 for demographics). Within a week following the intervention period, participants underwent post-intervention anxiety and fitness testing. The study spanned across an entire academic term, with post-intervention testing finishing the week before McMaster's examination period started.

Intervention Protocol

Exercise group.

The moderate intensity exercise group involved three aerobic exercise sessions per week over nine weeks, for a total of 27 exercise sessions. As per a previous protocol utilized by Paolucci et al. (2018), each session took place in an exercise facility at McMaster University, and involved a three-minute warm up at 50W, a 27.5-minute personalized moderate intensity protocol, and a two and a half minute cool down at 50W. This duration of moderate intensity exercise was used in Paolucci et al. (2018)'s protocol to match the workload of a high-intensity interval training group, and was kept the same for the current design given it successfully reduced general anxiety in young adults in their study. During the moderate intensity protocol participants cycled against 40% of the maximum wattage achieved during their VO₂peak test, to achieve between 65-75% of their VO₂peak heart rate (Paolucci et al., 2018). A trained member of the research team supervised all sessions to ensure the RPE and HR reflected a moderate intensity, as well as to ensure participant safety and adherence. RPE and HR was recorded by a member from the research team immediately after warm-up, every two minutes within the

moderate portion, immediately at the end of the moderate portion, and following cool down. Wattage was increased or decreased by 5W following any HR recording that fell outside of the specified moderate intensity range.

On the third and final exercise session of the week, the STAI-6 was administered immediately before (Time 1) and 10 minutes after (Time 2) the exercise session to assess acute state anxiety changes following exercise. The 10-minute delay between the cessation of the exercise session and the second STAI-6 administration was spent in quiet rest without cell phone use or interaction with the experimenter.

Control group.

The non-exercise control group was instructed to remain inactive during the nine week intervention. Two STAI-6 questionnaires were administered 40 minutes apart each Friday through email. This protocol was used to match the date, timing and number of STAI-6 administrations with the exercise group.

Statistical Analysis

All data was analyzed using IBM SPSS Statistics Software 25. 3.63% of the data was missing, which was subsequently imputed using expectation-maximization (Tabachnick & Fidell, 2007). Normality was assessed through visual inspection of histograms and the Kolmogorov-Smirnov statistic. Homogeneity of variance was assessed through Levene's test. One control participant (2017565) was removed due to non-adherence to the intervention protocol. Alpha level was set to 0.05 for all main analyses, and effect sizes are reported as partial eta square since it isolates the proportion of variance a variable explains that cannot be explained by other variables in the analysis (Fields, 2009). These effect sizes can be interpreted along a continuum, ranging from small (.01), medium (.06) and large (.14) (Miles & Shevlin, 2001).

Manipulation check

HR and RPE were analyzed to confirm that the exercise intervention reached the desired moderate intensity (65-75% peak HR and 12-13 RPE, respectively). We calculated average HR (excluding warm-up and cool down) by summing the average reported value for each session [Session 1 HR (S1) = (HR1+ HR2+ ... + HR14)/14] and then dividing by the total number of exercise sessions [(S1+ S2+ ... +S27)/27]. For each individual, an average RPE was calculated using the same protocol. A Pearson's correlation was used to assess the relationship between these two measures of intensity.

Anxiety

Baseline anxiety characteristics

To ensure no group differences at baseline, one-way ANOVAs were conducted on general anxiety and state anxiety. Anxiety severity subgroups were determined using baseline general anxiety (baseline-BAI), with a score of 11 or greater being indicative of functionallyrelevant anxiety, and 10 or lower being indicative of minimal anxiety (Karsten et al., 2011). Oneway ANOVAs were also conducted to ensure baseline general and state anxiety did not differ between groups within each severity subgroup, or by sex. To confirm the expected relationship between general and state anxiety, a Pearson's correlation was run between baseline general anxiety and baseline state anxiety (baseline-STAI-6). A paired samples t-test was conducted between baseline state anxiety and resting state anxiety week one of the intervention to ensure Time 1 scores in the exercise group were not inflated due to the onset of starting a new exercise protocol.

General anxiety

To evaluate whether general anxiety was lower following exercise training, a univariate ANCOVA was conducted on post-intervention general anxiety with the between-subjects factors of group (exercise, control) and anxiety severity (functionally-relevant, minimal), and the covariate of baseline aerobic fitness. Post-hoc pairwise comparisons were conducted on the estimated marginal means to investigate simple effects. To test the secondary hypothesis that anxiety severity moderates this relationship, the potential moderation was examined using Model 1 in the PROCESS macro software version 2.6 for SPSS (Hayes, 2012). 10,000 bootstrap simulation procedures were computed, and a 95% confidence interval that does not cross zero is considered indicative of a significant effect (Hayes, 2012; Hayes & Rockwood, 2017). In this analysis, the dependent variable was post-intervention general anxiety, the independent variable was group, the potential moderator was baseline anxiety severity, and the covariate was baseline aerobic fitness.

State anxiety

To assess if an acute exercise bout reduces state anxiety over the course of training, a repeated measures ANCOVA was conducted on the average change in state anxiety (Time 2 minus Time 1) with the between-subjects factors of group, the within subject factor of week (Weeks 1 to 3, Weeks 4 to 6, Weeks 7 to 9), and the covariate of baseline aerobic fitness. Posthoc pairwise comparisons on the estimated marginal means were used to assess simple effects, with a Bonferroni-correction applied to multiple comparisons.

Aerobic fitness

A repeated measures ANCOVA was conducted to assess change in aerobic fitness with the between-subjects factor of group, the within-subjects factor of time (baseline, postintervention) and the covariate of sex. Post-hoc pairwise comparisons on the estimated marginal

means were used to assess simple effects. In addition, Pearson's partial correlations were used to assess the relationships between change in aerobic fitness with 1) change in general anxiety, and 2) increases in acute state anxiety changes, controlling for sex.

	п	Exercise M (SD)	п	Control M (SD)
Sample size	27		28	
Age	27	19.56 (1.45)	28	19.07 (1.27)
BMI (kg/m ²)	27	24.90 (5.51)	28	22.54 (2.65)
Baseline VO ₂ peak (ml/min/kg)	27	26.94 (6.95)	28	28.04 (6.49)
Baseline state anxiety	27	13.15 (3.36)	28	12.29 (4.83)
Baseline general anxiety	27	11.89 (8.81)	28	12.39 (9.19)
Baseline minimal anxiety severity	14	5.57 (3.18)	16	5.87 (2.55)
Baseline functionally-relevant anxiety severity	13	18.69 (7.78)	12	21.08 (7.38)

RESULTS

Table 1. Demographic information.

Manipulation check

All the participants in the exercise group attended the full 27 exercise sessions; in the event of a missed session a make-up session was rescheduled and completed within 24 hours. Collapsed across exercise sessions, HR reflected a moderate intensity protocol (140 ± 6 beats/minute), and RPE reflected a light intensity protocol (11 ± 1 out of 20, "light").

Furthermore, there was no significant relationship between these two measures [r(27) = .012, p = .95].

Anxiety

Baseline anxiety characteristics

There was no significant baseline differences in general [F(1,53) = .043, p = .84] or state anxiety [F(1,53) = .59, p = .45] between groups. A total of 25 of 55 participants were experiencing functionally-relevant anxiety at baseline ($M_{BAI} \pm SD = 19.84 \pm 7.53$; $M_{STAI-6} = 14.20$ \pm 4.58), and within this severity subgroup there were no significant difference in general or state anxiety between the exercise and control groups [F(1,23) = .62, p = .44; F(1,23) = .22, p = .65], respectively. A total of 30 out of 55 participants were experiencing minimal anxiety at baseline $(M_{BAI} = 5.73 \pm 2.82; M_{STAI-6} = 11.47 \pm 3.36)$, and again there was no significant difference in general or state anxiety scores between groups [F(1,28) = .084, p = .77; F(1,28) = .23, p = .64], respectively. There was also no significant baseline differences in general or state anxiety between males and females [F(1,53) = 3.07, p = .085; F(1,53) = 1.60, p = .21]. There was a significant relationship between baseline general anxiety and baseline state anxiety [r(53) = .47], p < .001], such that those with higher general anxiety over the seven days prior to baseline testing were also endorsing higher state anxiety at baseline. There was no significant difference in baseline state anxiety and Time 1 state anxiety the first week of the intervention in the exercise [t(26) = .36, p = .72] or control group [t(27) = -1.65, p = .11].

General anxiety

There was a significant interaction between group and anxiety severity $[F(1,50) = 4.42, p = .041, \eta_p^2 = .081]$ when controlling for baseline aerobic fitness. To examine this interaction further, the simple effect of group was examined for the two levels of anxiety severity. Pairwise

comparisons showed a significant difference in general anxiety between the exercise and control groups for those with functionally-relevant anxiety at baseline $[F(1,50) = 9.53, p = .003, \eta_p^2 = .16]$. Functionally-relevant anxiety at baseline was associated with significantly lower general anxiety following exercise than non-exercise ($M_{EM} \pm SD = 9.99 \pm 9.04 vs. 20.65 \pm 8.55$). Critically, for those with functionally-relevant anxiety at baseline, exercise reduced anxiety so much so that they no longer met the criteria of having functionally-relevant anxiety. There was no significant difference in general anxiety at the end of the intervention between exercise and non-exercise for the minimal anxiety subgroup [$F(1,50) = .07, p = .79, \eta_p^2 = .001$] (see Figure 1).



Figure 1. Average post-intervention general anxiety (BAI) scores as a function of group and anxiety severity. Covariate: baseline aerobic fitness = 27.50. * indicates significant difference of p < .05 pairwise comparison. The red dotted line indicates cut-off for functionally relevant anxiety, and error bars represent standard error of the mean.

The potential moderating effect between group and anxiety severity was followed up in
PROCESS. There was a main effect of group [B = -5.30, SE = 2.30, $t(50) = -2.30$, $p = .026$, CI =
-9.92 to68] and severity [B = 6.63, SE = 2.53, $t(50) = 2.62$, $p = .012$, CI = 1.55 to 11.70].
Importantly, the interaction between group and baseline anxiety severity was significant $[B = -$
9.84, SE = 4.68, $t(50) = -2.10$, $p = .041$, CI = -19.23 to -0.44], and adding the interaction term
explained significantly more variance in post-intervention general anxiety [$\Delta R^2 = .063$, $F(1,50) =$
4.42, $p = .041$]. Specifically, there was a significant relationship between group and anxiety
severity for functionally-relevant anxiety at baseline [B = -10.66, SE = 3.45, $t(50)$ = -3.09, p =
.0033, $CI = -17.60$ to -3.73], such that the subgroup with functionally-relevant anxiety had lower
general anxiety following exercise than non-exercise. In contrast, there was no significant
relationship between group and anxiety severity for the minimal anxiety subgroup at baseline [B
=83, SE = 3.12, $t(50)$ =27, p = .79, CI = -7.09 to 5.44].

Predictor	В	SE	р	95% CI	
VO ₂ pre	-0.19	0.19	0.320	-0.58	0.19
Group	-5.30	2.30	0.026	-9.92	-0.68
Severity	6.63	2.53	0.012	1.55	11.70
Group x Severity	-9.84	4.68	0.041	-19.23	-0.44

Table 2. Linear model of predictors of post-intervention general anxiety scores.

State anxiety

When assessing the effect of the intervention on state anxiety change, there was a significant group by week interaction [F(2,104) = 3.31, p = .040, $\eta_p^2 = .060$] when controlling for baseline aerobic fitness. Analysis of simple effects revealed there was a simple effect of group

during weeks 4 to 6 [F(1,52) = 15.41, p < .001, $\eta_p^2 = .23$] and 7 to 9 [F(1,52) = 9.36, p = .003, $\eta_p^2 = .15$] of the intervention. State anxiety reductions were significantly larger in the exercise group than the control group in the middle ($M_{EM} \pm SD = -1.99 \pm 1.79 \text{ vs. } -.091 \pm 1.79$) and end of the intervention ($-1.74 \pm 1.59 \text{ vs. } -.43 \pm 1.58$). However, there was no simple effect of group during the first three weeks of training [F(1,52) = 2.90 p = .094, $\eta_p^2 = .053$], such that there was no significant difference in state anxiety change between the exercise and control group ($-1.05 \pm 1.44 \text{ vs. } -.39 \pm 1.44$; Figure 2). There was also a simple effect of week within the exercise group [$F(1,51) = 4.39, p = .017, \eta_p^2 = .15$]. Bonferroni-corrected post-hoc comparisons demonstrate that state anxiety reductions in the middle three weeks (-1.99 ± 1.79) were larger (p = .021) than the first three weeks of exercise training (-1.05 ± 1.44), but not significantly different (p = 1.00) from the last three weeks of training (-1.74 ± 1.59).



Figure 2. Average change in state anxiety (STAI-6; Time 2 minus Time 1) broken down into the beginning, middle, and end of the intervention. Covariate: baseline aerobic fitness = 27.50. * indicates significant difference of p < .05 pairwise comparison. Error bars represent standard error of the mean.

Aerobic fitness

When assessing the effect of the intervention on aerobic fitness, there was a significant group by time interaction $[F(1,52) = 4.03, p = .05, \eta_p^2 = .072]$ when controlling for sex. Post-hoc pairwise comparisons demonstrated there was a simple effect of time in the exercise group $[F(1,52) = 15.78, p < .001; \eta_p^2 = .23]$, with aerobic fitness being significantly higher at post-intervention than baseline ($M_{EM} \pm SD = 30.09 \pm 4.90 \text{ vs. } 27.37 \pm 5.06$). However, there was no significant difference in VO2peak at baseline or post-intervention in the control group $[F(1,52) = 1.38, p = .25 \eta_p^2 = .026; 27.62 \pm 5.06 \text{ vs. } 28.41 \pm 4.90]$ (Figure 3). Furthermore, change in aerobic fitness was not significantly correlated with change in general anxiety [r(52) = -.016, p = .91] or state anxiety [r(52) = -.008, p = .96].



Figure 3. Average aerobic fitness (VO₂peak) at baseline and post-intervention as a function of group. * indicates significant difference of p < .05 pairwise comparison. Covariate: sex = .85. Error bars represent standard error of the mean.

DISCUSSION

The current study aimed to examine the effects of a moderate intensity aerobic exercise protocol on both general and state anxiety in inactive young adults. Across the entire training protocol, general anxiety was only significantly lower following exercise in the subgroup experiencing functionally-relevant levels of anxiety; no group differences were found in the subgroup experiencing minimal anxiety. A single bout of aerobic exercise only reduced state anxiety as of the fourth to sixth weeks of training.

General anxiety

Only those suffering from functionally-relevant anxiety symptoms (BAI \geq 11) had significantly lower general anxiety scores at the end of the exercise intervention compared to non-exercise. These changes have clinical significance, such that those with functionally-relevant anxiety at baseline no longer satisfied this criteria following exercise training. This finding is consistent with previous research highlighting the efficacy of aerobic exercise training on functionally-relevant anxiety (Herring et al., 2010; Stubbs et al., 2017). Notably, just under half of the sample met the criteria for at least having a subthreshold anxiety disorder. This high prevalence is likely due to the majority of our sample being young females enrolled in postsecondary education. Relative to males, females have a higher prevalence of anxiety disorders as well as more disabling symptoms (McLean et al., 2011; Steel et al., 2014). Therefore, the prevalence and severity of general anxiety within the current sample may not be representative of how anxiety symptoms present in young males. Furthermore, post-secondary students have high rates of mental health difficulties. Forty-three percent reported the need for help managing their mental health in the past year (Zivin, Eisenberg, Gollust, & Golberstein, 2009), with anxiety concerns being the number one reason students sought on-campus mental health services

(CCMH, 2018). Although many of the external factors that are associated with high anxiety in university students (e.g., pressure to succeed, financial strain, body image disturbance, sleep quality; Beiter et al., 2015) are also representative of the external pressures faced by young adults not in school, further research that replicates the effect of exercise training on the functionally-relevant anxiety of young adults not enrolled in post-secondary school would increase the generalizability of this finding.

The subgroup with minimal anxiety at baseline did not have lower general anxiety after the exercise intervention compared to those who did not exercise. Within this subset of participants, having such low baseline scores may not have allowed for any further reduction in symptoms. Indeed, floor effects are common in research looking at mental illnesses (Salmon, 2001). Future studies should include an anxiety-screening questionnaire to ensure the studied sample presents with functionally-relevant general anxiety prior at baseline.

There was no relationship between changes in aerobic fitness and change in general anxiety. To date, the cross-sectional findings regarding the relationship between aerobic fitness and anxiety symptoms are mixed. While some studies find that lower mental illness symptoms and greater emotional well-being are associated with higher aerobic fitness (Galper, Trivedi, Barlow, Dunn, & Kampert, 2006), others do not. Instead, they find associations with self-reported physical activity (De Mello et al., 2013; Lindwall, Ljung, Hadžibajramović, & Jonsdottir, 2012). Critically, interventional research has shown that improvements in aerobic fitness are not necessary for an exercise group to experience reductions in their anxiety symptoms (Wipfli et al., 2008). Therefore, the benefits of aerobic exercise on anxiety may be driven by other exercise-related physiological or psychological changes that are not directly captured by an increase in aerobic capacity (see discussion below).

State anxiety

Significant reductions in state anxiety that differ from the control group did not emerge until weeks 4 to 6 of training. Although this is inconsistent with meta-analyses that report reduced anxiety following a single acute bout of aerobic exercise (Ensari et al., 2015; Petruzzello et al., 1991), there was a unique social component to our study that may have minimized the effect at the start of training. Typically, studies examining exercise-induced change in state anxiety test participants one-on-one. That was not the case here. Instead, we tested participants in groups of three (as part of their training session). However, performing the acute exercise bout alongside an unfamiliar peer introduces a variety of confounding factors that may have minimized the acute anxiety relief from exercise, especially at the beginning of the training. For example, individuals who do not regularly exercise feel less confident in their ability to project a "desirable" image when exercising around others (Cumming & Thøgersen-Ntoumani, 2011). Moreover, affect and enjoyment of exercise are reduced when exercising alongside an individual perceived as attractive compared to when exercising alone (Plante et al., 2011). It is plausible that such social comparisons could actually be anxiety provoking, thus effectively cancelling out the anxiety relief from exercise. Such social comparison would have also been strongest at the start of the training, but may have dissipated over the course of the intervention as the participants became more familiar with each other (Mendes et al., 2001).

Another unique feature of this study was that we administered the state anxiety questionnaire to the control group via email. The most commonly utilized control group in acute state anxiety research involves participants answering a state anxiety questionnaire in a controlled laboratory setting, sitting in quiet rest for the same duration as the exercise bout, and then answering the questionnaire again (Ensari et al., 2015). Administering the questionnaires by

email allowed us to capture natural fluctuations in state anxiety evoked by external factors in daily life. However, given this introduction of extraneous variables, it may weaken our ability to compare non-exercise with the efficacy of acute exercise on state anxiety over training. In future studies, utilizing a more rigorous control group will allow for further elucidation of the differences in exercise and non-exercise on state anxiety.

In this study we aimed to compare our findings to Hale & Raglin (2002), who did not find an effect of training across eight weeks of aerobic exercise. We hypothesized that since their study did not account for baseline fitness differences, it was possible that pre-existing physiological or psychological adaptations that may contribute to greater state anxiety reductions in high fit individuals could have already been present (Dishman et al., 1994; Hallgren et al., 2010). In our study, we selectively recruited inactive participants (less than 60 minutes of moderate-to-vigorous physical activity per week), and controlled for aerobic fitness at baseline. However, given that we did not find significant state anxiety reductions until weeks 4 to 6 of training, it is difficult to speculate on how these studies compare. We also did not observe a correlation between state anxiety change and aerobic fitness. This is similar to what we found with general anxiety, suggesting that both measure of anxiety may be influenced by exercise training related factors other than aerobic fitness per se.

Potential mechanisms

One potential mechanism through which aerobic exercise training may impact *both* general anxiety and state anxiety response is through regulation of the stress response, comprised of the autonomic nervous system and the HPA axis. Autonomic nervous system activation during a threat results in noticeable physiological changes, such as a rapid heartbeat, sweating and shortness of breath. Critically, individuals with anxiety disorders exhibit high levels of anxiety

sensitivity: a fear of the sympathetic-arousal associated with anxiety, because of the perception that such arousal will inevitably result in physiological, psychological, or social consequences (Olatunji & Wolitzky-Taylor, 2009; Reiss, Peterson, Gursky, & Mcnally, 1986). In addition, the activation of the HPA axis during a threat ultimately results in increased release of glucocorticoids such as cortisol, which helps facilitate an adaptive response to manage the threat (Sapolsky, Romero, & Munck, 2000). Due to chronic activation of this pathway in stress and anxiety disorders, a dysregulated HPA response to a threat is typically observed in anxious individuals (Abelson, Khan, Liberzon, & Young, 2007; Perlis et al., 2013).

Importantly, physical exercise is also a stressor, meaning engagement in a bout of aerobic exercise also activates the stress response (Hackney, 2006). Aerobic exercise training repeatedly exposes an individual to sympathetic arousal associated with anxiety symptoms (rapid heart rate, difficulty breathing, sweating). According to interoceptive exposure theory, repeated exposure to somatic symptoms in a controlled exercise environment may gradually reduce fear of such arousal (Beck & Shipherd, 1997; Boswell et al., 2013). Indeed, prior research has shown that as little as six 20-minute aerobic exercise sessions over two weeks reduces anxiety sensitivity, and this change mediates the positive effects of aerobic exercise on general anxiety symptoms (Broman-Fulks & Storey, 2008; Smits et al., 2008). Since reductions in anxiety sensitivity can emerge as early as two weeks into aerobic exercise training, this dampened reactivity to sympathetic arousal could also be contributing to the state anxiety reductions that we observed following the fourth to sixth weeks of training. Reduced anxiety sensitivity may also have helped the exercise group perceive their general anxiety symptoms outside of exercise contexts as less anxiety provoking and burdensome.

Additionally, according to the cross-stressor adaptation hypothesis, regular exposure to exercise (a *physical* stressor) will also reduce the HPA axis' response to a *psychological* stressor (Sothmann et al., 1996). Indeed, fit individuals demonstrate an attenuated cortisol response (Traustadóttir, Bosch, & Matt, 2005; Wood, Clow, Hucklebridge, Law, & Smyth, 2018), and a faster recovery to resting hormone levels (Luger et al., 1987) in comparison to their unfit counterparts following a psychological stressor. Furthermore, twelve weeks of endurance training results in a reduced HPA response to a psychological stressor relative to baseline (Klaperski, von Dawans, Heinrichs, & Fuchs, 2014). Compared to untrained individuals, athletes have blunted HPA activation and a more rapid axis recovery resulting in significantly less state anxiety in response to a psychological stressor (Rimmele et al., 2009). These findings suggest that regular exercise may contribute to less general anxiety symptoms by reducing the physiological activation by psychological stressors. Although the initial HPA rebound following the exercise stressor seemed to be enough to provide psychological reprieve in the form of improved state anxiety, the novel stress of a new exercise program, whose physical manifestations overlap with the symptoms of anxiety, may have initially exacerbated state anxiety (Graeff and Junior, 2010; Salmon, 2001). This may be in part why we observed minimal symptom relief during the first three weeks of training. However, as training progressed, the stress system adapts to provide a faster rebound from the physical exercise stressor and greater psychological symptom relief. In our study, this emerged between weeks four and six.

Prescription

The current exercise protocol was associated with lower general anxiety in those with functionally-relevant anxiety at baseline, and reductions in state anxiety after four weeks of training. With respect to exercise intensity, our objective intensity measure of average HR was

indeed reflective of a moderate intensity protocol, although our subjective measure of RPE was reflective of a light intensity protocol. Furthermore, there was no relationship between the subjective and objective measures of intensity. One possible explanation for the discrepancy in the subjective and objective intensity measures is the influence of our exercise environment on RPE. The facility participants exercised in consistently played loud, upbeat music through speakers. Importantly, lower RPE scores are reported when an individual completes a moderate intensity exercise bout with music playing when compared to silent exercise (Potteiger, Schroeder, & Goff, 2000) or dialogue with another person (Miller, Swank, Robertson, & Wheeler, 2010). Therefore, the presence of music during our exercise sessions may have reduced our participants' perceptions of how strenuous the exercise task felt.

With respect to exercise duration, participants in the exercise group each completed 82.5 minutes of moderate intensity cycling each week. This is consistent with previous research showing that three aerobic sessions per week lasting no more than 30 minutes each significantly reduces general anxiety (Wipfli et al., 2008). However, this specific duration is below the recommended Canadian Physical Activity Guidelines of 150 minutes of moderate-to-vigorous physical activity each week (Tremblay et al., 2011). The current intervention may have been lesser than research has recommended, but it has important implications for exercise prescription specifically in individuals with functionally-relevant anxiety. While most adults with a clinical mental illness report understanding and believing in the benefits of exercise on both physical and mental health (Firth et al., 2016; Ussher, Stanbury, Cheeseman, & Faulkner, 2007), few are actually regularly engaging in exercise (Helgadóttir et al., 2015). In both healthy and clinically-anxious adults, one of the most commonly cited barriers for lack of engagement in physical activity is lack of time (Gibala, Little, Macdonald, & Hawley, 2012; Pelletier,

Shanmugasegaram, Patten, & Demers, 2017). In addition, individuals with anxiety disorders may also face barriers to engagement in exercise directly associated with their disorder symptoms (Ma et al., 2009). For example, an individual who deals with functionally-relevant anxiety may be anxious at the prospect of attending a crowded gym, experiencing anxiety symptoms through aerobic exercise, or potentially suffering a panic episode in front of others. Furthermore, individuals with an anxiety disorder who take anxiolytic medications like serotonin-norepinephrine reuptake inhibitors and selective serotonin reuptake inhibitors often experience medication-induced fatigue and weight gain (Santarsieri & Schwartz, 2015), which can discourage physical activity. Therefore, although not ideal for accruing concurrent benefits for physical health, the current exercise duration of ~80 minutes was adequate to positively impact functionally-relevant general anxiety, which further highlights its utility as a preliminary prescription for managing anxiety symptoms.

Limitations and Future Directions

One important limitation of this study is the lack of a clinically validated diagnostic screening tool for anxiety, which prevented us from identifying the specific anxiety disorders present in our sample. Although anxiety disorders can be described holistically through shared physiological, psychological and behavioral symptoms, there are discrete aspects of each disorder, such as the types of situations or items that evoke these symptoms, as well as the accompanying cognitive ideation. For example, panic disorder involves recurrent, unexpected episodes of intense but transient surges in fear and physiological discomfort. In contrast, generalized anxiety disorder involves more prolonged and constant symptoms of restlessness and worry evoked by a variety of external situations (American Psychiatric Association, 2013). Treatment can drastically vary depending on the specific anxiety disorder(s) an individual suffers

from, suggesting that different components of therapy may more positively impact different anxiety symptoms. For example, cognitive restructuring may be more beneficial for general anxiety disorder, while exposure to somatic symptoms may be more effective for reducing anxiety sensitivity in individuals who suffer from panic disorder. Without knowing which clinical and subclinical anxiety disorders were present in the sample, it is difficult to presume whether the treatment effects and proposed mechanisms would generalizes across all of the disorders. In order to address this future research could recruit specific anxiety disorders to compare the efficacy of exercise training across the different conditions.

Another limitation in the present study is the potentially confounding effect of social support. Each exercise session contained up to three exercisers, as well as a research student who oversaw each session. Given the longitudinal nature of this study, a participant experienced regular social interaction with other participants, as well as with the research student. Across the nine week intervention, increased rapport and comfort among exercise groups was evident. Importantly, increases in social support may have had a confounding effect on the state anxiety training effect. Experiencing social support immediately prior to an acute stressor can reduce the HPA response to that stressor (Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003). Socializing with the experimenter and other participants before exercise could have contributed to the effect of exercise on state anxiety, through the buffering of the HPA axis response. Although future studies could have exercise sessions that only include one participant, it would be difficult to remove all social interaction with the research student. Therefore, future studies should include a questionnaire to assess change in perceived social support across the aerobic exercise intervention.

Although there is promising evidence for aerobic exercise as an intervention to help manage anxiety symptoms, research suggests that these effects are lesser than those elicited by pharmacological treatment or CBT (Bandelow et al., 2015). A novel area of research has begun to explore the effects of combining exercise with another common treatment for anxiety, with preliminary support for additive benefits when combined with CBT. For example, in panic disorder, four weeks of CBT combined with three 30-minute aerobic exercise sessions per week resulted in greater reductions in anxiety seven months later compared to stretching and movement sessions (Gaudlitz, Plag, Dimeo, & Ströhle, 2015). Furthermore, greater improvements in anxiety were observed in individuals undergoing CBT who also increased their total physical activity time (Merom et al., 2008). In contrast, preliminary reports combining aerobic exercise with anxiolytic medications find comparable effects to anxiolytic medications alone (Wedekind et al., 2010). Further investigation is needed to understand how exercise interacts with other efficacious treatments to facilitate anxiety symptom reduction.

Future research is needed to assess the potential psychological and physiological mechanisms of change. For example, to test exposure theory, administering an anxiety sensitivity self-report measure (i.e., the Anxiety Sensitivity Index-3; (Reiss et al., 1986)) at multiple points during the intervention would allow researchers to track changes in anxiety sensitivity induced by exercise. To test the cross-stressor hypothesis, examining the acute HPA response through blood draws immediately before and after acute exercise would provide insight into whether regulation of the HPA axis occurs through moderate intensity aerobic training to mitigate the effects of psychological stress. Finally, administering the protocol to individuals with different types of anxiety (such as generalized anxiety or panic) will allow for greater understanding of the generalizability of physical exercise for managing anxiety disorders.

Conclusions

After nine weeks of aerobic exercise training, general anxiety was lower in the exercise subgroup suffering from functionally-relevant anxiety at baseline compared to no exercise. A single acute exercise bout reduced state anxiety as of weeks four to six of training compared to no exercise. Collectively, these findings demonstrate the importance of regular engagement in aerobic exercise for managing acute and more chronic manifestations of anxiety.

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Appendix: Study Materials

Beck Anxiety Inventory

Borg Rating of Perceived Exertion Scale

Short form of the State-Trait Anxiety Inventory

Beck Anxiety Inventory (Beck, Brown, Epstein & Steer, 1988)

Name:_____ Date / /

Below is a list of common symptoms of anxiety. Please read through each list item. Indicate how much you were bothered by each symptom listed on the left during the last week, including today, marking an X in the degree of disturbance corresponding to a column of cells on the right.

	Symptoms	How much you were bothered					
N⁰		Nothing 0	Weak 1	Moderate 2	Strong 3		
		It did not bother at all	It bothered a little	It bothered me a lot but I could stand it	l almost could not stand it		
1	Numbness or tingling						
2	Hot sensation						
3	Wobbly						
4	Incapable of relaxing						
5	Fear of the worst happening						
6	Dizziness or lightheadedness						
7	Heart pounding or racing						
8	Restless						
9	Terrified						
10	Nervous						
11	Feeling of suffocation						
12	Hands trembling						
13	Trembling		i i i i i i i i i i i i i i i i i i i				
14	Fear of losing control						
15	Difficulty breathing						
16	Fear of dying						
17	Frightened						
18	Indigestion or discomfort in the abdomen						
19	Fainting						
20	Red Face						
21	Sweating (not due to heat)						
SCO	RE:			-			

Rating	Perceived Exertion
6	No exertion
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Borg Rating of Perceived Exertion Scale (Borg, 1982)

Self-evaluation questionnaire (Y-6 item) 6-item short form of the State-Trait Anxiety Inventory (Marteau & Bekker, 1992)

Participant ID:		
Date:		_

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the most appropriate number to the right of the statement to indicate how you feel right now, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	Not at all	Somewhat	Moderately	Very much
1. I feel calm	1	2	3	4
2. I am tense	1	2	3	4
3. I feel upset	1	2	3	4
4. I am relaxed	1	2	3	4
5. I feel content	1	2	3	4
6. I am worried	1	2	3	4

Please make sure that you have answered *all* the questions.