DOES EXERCISE REDUCE ANXIETY SENSITIVITY? A SYSTEMATIC REVIEW AND META-ANALYSIS

A DISSERTATION

SUBMITTED TO THE FACULTY

OF

THE GRADUATE SCHOOL OF APPLIED AND PROFESSIONAL PSYCHOLOGY

OF

RUTGERS,

THE STATE UNIVERSITY OF NEW JERSEY

BY

AMBER MARGETICH

IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE

OF

DOCTOR OF PSYCOLOGY

NEW BRUNSWICK, NEW JERSEY AUGUST 2019

APPROVED: _____
Brandon Alderman, Ph.D.

_____
Kenneth Schneider, Ph.D.

DEAN: _____
Francine Conway, Ph.D.

Copyright 2019 by Amber Margetich

ABSTRACT

Anxiety is a commonly diagnosed and experienced mental health disorder that places a large burden on public health and overall quality of life. Traditional treatment approaches for anxiety disorders include antidepressants and psychotherapy. Although these treatments are effective for some, they are not always beneficial. Due to its relative accessibility and minimal adverse side effects, physical activity and/or exercise may be an effective approach for the prevention and treatment of anxiety. The effects of exercise on anxiety have been reported to be moderate-to-large in magnitude, but the underlying mechanisms remain relatively unknown. Recently, investigators have examined anxiety sensitivity (AS), or an individual's fear of anxiety or arousal-related physical sensations, to advance understanding of the exercise and anxiety relationship. The purpose of this meta-analysis was to estimate the population effect size for the effects of exercise on anxiety sensitivity. A two-tiered approach was used to locate all available studies (n= 276) and included (n = 8) for the current review. The first approach involved a computerized search using *Google Scholar, PubMed, PsychINFO, MEDLINE, and Web of Science.* The second approach included a complete examination of all relevant journals (e.g., Health Psychology, Behavioral Medicine), as well as the reference lists of the published papers found in the initial search. Independent variables included exercise and/or physical activity and at least one of the outcome variables was a measure of AS. Hedges' *g* effect sizes were computed for each study and random effects models were used for all analyses. Across the eight studies, we found a mean ES of 0.52 for acute exercise effects on reducing ASI and a mean ES of 0.86 for studies using chronic exercise to reduce ASI symptoms. Overall, the effects of acute exercise were primarily consistent across different modes of exercise toward reducing ASI (range; 0.30-0.70). A larger range of mean ES was observed for studies utilizing chronic protocols (range; -0.20-2.50). The overall mean ES for all included studies was 0.70, indicating a large ES for exercise in reducing ASI. Future research evaluating the efficacy of exercise on AS may benefit from larger sample sizes and the utilization of interventions that control for exercise intensity, type, and duration.

ACKNOWLEDGEMENTS

Thank you to my parents, for supporting me throughout all aspects of life, and for instilling in me the hard work and dedication needed to succeed throughout the seemingly endless years of school. I truly would not be where I am today if it were not for you, and I am eternally grateful. Thank you to my fiancé Andrew, for not only providing emotional support for the last nine years, but for making me laugh every single day. I am so fortunate to have you in my life, and I am beyond excited to continue throughout life with you! Thank you to my colleagues and advisors at GSAPP, for getting me through the longest days, hardest assignments, and challenging clinical experiences. Lastly, thank you to my committee, for your patience and flexibility. Your guidance and support are the reason this exciting project was completed in the time frame we had, and I am so grateful to have had you on my side.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter I

Literature Review

Introduction

Anxiety has been defined as an emotion characterized by feelings of tension, heightened vigilance, excessive and inappropriate worrying, and physical symptoms of arousal, such as increased muscular tension and elevated heart rate (Stein & Craske, 2017). Although some experts contend that an optimal amount of anxiety is beneficial and can help individuals plan for the future (LeDoux, 2015), when anxiety begins to meaningfully interfere in a person's life, it is considered a disorder. Clinical anxiety has been defined by the Surgeon General's Report on Mental Health (U.S. Department of Health and Human Services [USDHHS], 1999) as the pathological equivalent of normal fear, marked by disturbances of mood, thinking, physiological activity, and accompanying behavior. Anxiety is the mostly commonly diagnosed and experienced mental health disorder besides substance use disorders, and there are several common subtypes of anxiety, including (in order of prevalence): social phobia, specific phobias, panic disorder, posttraumatic stress disorder (PTSD), generalized anxiety disorder, agoraphobia, and obsessive-compulsive disorder (OCD). However, in the most recent edition of the Diagnostic and Statistical Manual of Mental Disorders (*DSM*-5), several new forms of anxiety were included (e.g., separation anxiety disorder, selective mutism) while PTSD and OCD were separated into categories distinct from the anxiety disorders. Although there are no specific causes of anxiety, Petruzzello (2015) contends that anxiety may result from chronic stress, which can develop from a variety of personal and environmental factors, such as poor eating habits, pressures from work, busy schedules, deadlines, lack of sleep, and finances. Chronic, unrelenting and uncontrollable stress often results in the feeling of being constantly alert or hypervigilant. Petruzzello further suggested that anxiety differs from stress in at least four distinct ways: (1) in

anxiety, the concern and perception of a threat are disproportionate to the actual threat involved, (2) there is involvement of cognitive and behavioral actions in order to avoid anxiety symptoms, (3) there often exists an experience of anxiety even after the threat-eliciting event or stimulus has subsided, and (4) anxiety can be a result of a perceived threat (i.e., there does not have to be an actual threat involved).

Traditional treatment approaches for anxiety disorders include antidepressants, including selective serotonin reuptake inhibitors (SSRIs) or serotonin and norepinephrine reuptake inhibitors (SNRIs) and psychotherapy, including cognitive behavioral therapy (CBT). Although these treatments have been shown to be effective for some, they are not always beneficial. For instance, there is often a high rate of partial or non-response to these forms of treatment and many patients cycle through a number of drug therapies and CBT before experiencing a reduction in symptoms. These traditional treatments for anxiety, including psychotherapy and medication, may also be associated with negative consequences, such as adverse side effects and the time and expense involved (Petruzzello, 2015). Psychotherapy can be limited due to the amount of therapists available in comparison to the amount of people seeking therapy, while medications are often associated with negative side effects, such as nausea, increased appetite and weight gain, and sexual dysfunction. Furthermore, medications often require extended periods of use. Both forms of treatment can also be costly, as copays are commonly required. The negative circumstances surrounding these traditional forms of treatment have led researchers and health care providers to focus their attention on alternative or adjunctive forms of treatment for anxiety, including various behavioral interventions. Due to its relative accessibility and minimal adverse side effects, physical activity and/or aerobic exercise seems to be an ideal behavioral approach for the prevention and treatment of anxiety.

Exercise and anxiety. The relationship between exercise and anxiety has been studied for nearly half a century. In one of the earliest published studies examining exercise and anxiety, Orwin (1974) described the use of exercise (running) for situational phobia in a 24-year-old woman with a fear of public restrooms. He reported that exercise was effective when used just prior to having the patient entering a fear-inducing situation, and that the "near lifelong phobia was removed in five short sessions with little psychiatric involvement" (p. 97). During the ensuing decades following this early case study, there has been considerable research supporting the use of exercise in both the prevention and treatment of anxiety. This literature has been summarized by a number of systematic reviews and meta-analyses (e.g., Bartley, Hay, & Bloch, 2013; Herring, O'Connor, & Dishman, 2010; Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991; Raglin, 1997; Stubbs et. al., 2017). Despite a half century of rigorous study, a number of issues remain unresolved, which has resulted in an unconvincing evidence base to support exercise as a first-line behavioral treatment or intervention for anxiety and other stress-related disorders. In particular, although the effects of exercise on anxiety are often reported to be of moderate-to-large in magnitude (e.g., Petruzzello et al., 1991; Stonerock et al., 2015), the underlying mechanisms through which exercise impacts anxiety remain relatively unknown. In addition, important individual-level characteristics that may moderate the effects of exercise on anxiety have yet to receive sufficient attention. Recently, investigators have begun to examine anxiety sensitivity, or an individual's fear of anxiety or arousal-related physical sensations, in an attempt to advance our understanding of the exercise and anxiety relationship (e.g., LeBouthillier & Asmundson, 2015).

Anxiety sensitivity. Anxiety sensitivity (AS) has been defined by Olatunji and Wolitzky-Taylor (2009) as "the fear of anxiety-related bodily sensations derived from beliefs that these

symptoms have harmful physical, psychological, or social consequences" (p. 974). Furthermore, it has been conceptualized by LeBouthilier and Asmundson (2015) as an "anxiety amplifier" (p. 252), as individuals with high levels of AS are more likely to become anxious and experience fear their own anxiety-related sensations, such as sweating, shortness of breath, increased heart rate, and muscle tension, essentially leading to emphasized feelings of anxiety. For instance, an individual with high AS may fear that the physical experience of elevated heart rate and heart palpitations may result in a heart attack. In contrast to trait anxiety, AS is specific to fears about bodily sensations, whereas trait anxiety reflects an overall tendency to respond with fear to a variety of stressors. Thus, AS represents a distinct construct, separate from other anxiety measures. AS has been examined extensively, particularly given its role in both the development and maintenance of anxiety and related disorders (Broman-Fulks & Storey, 2008; Medina et al., 2014; Smits et al., 2008).

Currently, cognitive behavioral therapy (CBT) serves as the gold-standard treatment for individuals with AS. Generally, CBT interventions work to change maladaptive beliefs central to the development and maintenance of psychological disorders through the utilization of three principle components: education, cognitive restructuring, and exposure (Smits, Berry, Tart, & Powers, 2008). When treating individuals with elevated AS, CBT incorporates interoceptive exposure (IE) combined with components of arousal reduction, including "intentional, repeated induction of anxious arousal symptoms via behavioral techniques" (Broman-Fulks & Storey, 2008, p. 118). IE involves exposing or carefully introducing individuals to higher levels of physical arousal, which are typically associated with anxiety and form core AS beliefs, but in a controlled fashion. This induction of arousal would include elevated heart rate, respiration, and other physiological symptoms. Interestingly and pertinent to the current review, physical

exercise results in increases in physiological arousal and is one strategy that has been used to help patients re-interpret or change their anxiety-related beliefs to associate these symptoms to exercise rather than to a threat or fear-inducing stimulus.

Sabourin, Stewart, Watt, and Krigolson (2015) explain, "in the case of IE for AS and associated conditions, theoretically, repeated exposure to physiological arousal should lead to a decrease in fearful responding by way of at least two separate mechanisms" (p. 265). This can be viewed through both cognitive and learning perspectives. The cognitive perspective suggests exposure to sensations that are feared without the seemingly dangerous consequences can lead one to re-evaluate and determine the arousal sensation to be less threatening (Chambless & Goldstein, 1981). According to the learning perspective, the fear of physiological arousal, which is typically considered the conditioned stimulus, occurs due to learned association with a previously negative or feared consequence. The goal of IE would be to present the conditioned stimulus without the negative consequence so that a new learning pathway occurs (i.e., between exercise and physiological arousal), thus leading to extinction of the initial conditioned-unconditioned relationship.

While CBT has been shown to be effective in decreasing AS in those with elevated levels, there are several reasons alternative forms of treatment, such as exercise, should also be examined as a possibility. Accumulating empirical evidence supports the notion that exercise may be used as a therapeutic strategy for improving anxiety and mood disorders more generally (Medina et al., 2014). Powers, Asmundson, and Smits (2015) have outlined how and why exercise could be utilized as an intervention for anxiety disorders. They explained, for example, that exercise can be free (e.g., walking/running), whereas CBT may incur a high financial cost for those seeking treatment; CBT trained therapists are often scarce depending on the location;

exercise does not have the negative side effects that medications may have; there is generally less stigma associated with exercise compared to psychotherapy and medications; and, more recently, exercise has been used as a transdiagnostic intervention, in that it may help to address underlying behavioral and biological factors that may ultimately express as symptoms of anxiety (e.g., cognitive or autonomic nervous system deficits). Lastly, Powers and colleagues emphasized that exercise not only has a positive impact on mental health, but also results in a number of physical health benefits as well.

Statement of Specific Hypotheses and Predictions

Thus far, several studies have empirically examined how exercise can be used as an intervention for AS. Smits et al. (2008) explain, "Exercise interventions, particularly those that involve moderate to vigorous activity, may exert mental health benefits not only by promoting persistence in adaptive actions but also by providing a procedure through which exposure to physiological sensations is achieved" (p. 690). This is particularly important, considering anxiety disorders are the most commonly diagnosed mental disorder, and the burden on the public health care system continues to rise (Asmundson et al., 2013). Although there has been an increasing number of published studies that have examined the effects of exercise on anxiety sensitivity over the past ten years, to date there has been no quantitative synthesis of the available empirical evidence. Thus, the goal of this systematic review and meta-analysis is to estimate the population effect size for the effects of exercise on anxiety sensitivity and to determine whether there are important and significant moderators of the relationship between exercise and anxiety sensitivity.

Chapter II

Method

Selection and Inclusion of Studies

A two-tiered approach was implemented to locate all studies for the current review. The first approach involved a computerized search using *Google Scholar, PubMed,* and a general article search through *Rutgers University Library*, which searches hundreds of databases simultaneously to identify articles. Key terms used in these searches included various combinations of "exercise," "exercise training," and "physical activity" cross-referenced with "anxiety" and "anxiety sensitivity." The second approach included a complete examination of all relevant journals (e.g., Psychophysiology, Health Psychology, Behavioral Medicine), as well as the reference lists of the published papers found in the initial search. Reference lists were cross-checked for additional sources as were all studies included in the recent Asmundson et al. (2013) and Stubbs et al. (2017) meta-analyses.

Criteria for inclusion in the review included all studies published in the English language incorporating examining the effects of exercise on anxiety sensitivity in human subjects. The independent variable in all of these studies had to be either exercise or physical activity and at least one of the outcome variables had to be a measure of anxiety sensitivity. Anxiety sensitivity was defined as the fear of bodily sensations related to anxiety, resulting from beliefs that these symptoms have harmful physical, psychological, or social consequences. The measures of anxiety sensitivity included the Anxiety Sensitivity Index (ASI), the Anxiety Sensitivity Index–Revised (ASI-R), and the Anxiety Sensitivity Index–3 (ASI-3).

Coding the Studies

Potential moderating variables of logical or theoretical relation to anxiety as well as those derived from previous meta-analyses (Petruzzello et al., 1991; Stonerock et al., 2015; Stubbs et al., 2017) as well as narrative reviews of this literature (Asmundson et al., 2013; Powers et al., 2015) were coded *a priori*. Key variables included characteristics related to participants, experimental design, exercise (e.g., frequency, intensity, duration, and type), and the dependent measure(s) of anxiety sensitivity.

Participant characteristics. The age of participants was coded as unreported or continuous in average years. Gender was coded as male, female, or mixed (male and female).

Experimental design characteristics. Studies were coded whether they are acute (one session of exercise), chronic (weeks to months of exercise participation), or correlational in nature. Correlational studies are those that compare anxiety sensitivity between fit and unfit individuals or between individuals who vary in their typical, often self-reported, leisure-time exercise or physical activity participation.

Exercise characteristics. The type of exercise was coded as aerobic or resistance exercise. Exercise was also coded for the type, intensity, and duration of the exercise bouts used in the study. Based on national guidelines (American College of Sports Medicine, 2013), intensity of exercise was coded for low ($\leq$63% HR_{max}; $\leq$42.5% $VO2_{max}$), moderate (65-76% HR_{max}; 42.6-62.5% $VO2_{max}$: 40-59% HRR), high ($\geq$77% HR_{max}; $\geq$62.6 $VO2_{max}$; 60-84% HRR), or not reported. Duration of exercise was coded in minutes.

Outcome measures. The most commonly used method to assess the construct of AS is the Anxiety Sensitivity Index (ASI). The ASI is a 16-item measure that assesses the degree to which one is concerned about the potentially negative consequences of anxiety symptoms (Olantunji &

Wolitzky-Taylor, 2009). There are several alternative versions of the ASI, including the Anxiety Sensitivity Index-Revised (ASI-R), Anxiety Sensitivity Index-3 (ASI-3), and Childhood Anxiety Sensitivity Index (CASI). The studies used in this review used the ASI, ASI-3, and ASI-R. The ASI-R and ASI-3 were developed to improve the multidimensional measure of AS. The Anxiety Sensitivity Profile (ASP) is another measure used to assess the fear of anxiety-related symptoms.

ES Calculation

Effect sizes were calculated using Hedges' (1981) formula for the standardized mean-change statistic, *g*,

$$g = \frac{M_E - M_C}{SD_{pooled}}$$

where M_E = mean of the experimental group (or postintervention mean task performance), M_C = mean of the comparison group (or preintervention mean task performance), and SD_{pooled} = pooled standard deviation of the two groups.

Data Analysis

Hedges' *g* effect sizes were calculated for each study using the formula above. An overall average effect size was calculated across all available studies that met the inclusion criteria.

Chapter III

Results

Search results

Following removal of duplicates from the study searches, 224 entries were considered at the title and abstract level. After that, 191 additional records were excluded based on the title and abstract as well as a further 25 excluded by not meeting inclusion criteria. Eight studies (Broman-Fulks et al. 2015; Mason & Asmundson 2018; LeBouthillier & Asmundson 2015; Broman-Fulks et al. 2004; Broman-Fulks et al. 2008; Smits et al. 2008; Sabourin et al. 2016; LeBouthillier & Asmundson 2017) met the inclusion criteria for the meta-analysis. A summary of the search results including reasons for exclusion is presented via a PRISMA diagram (Fig.1).

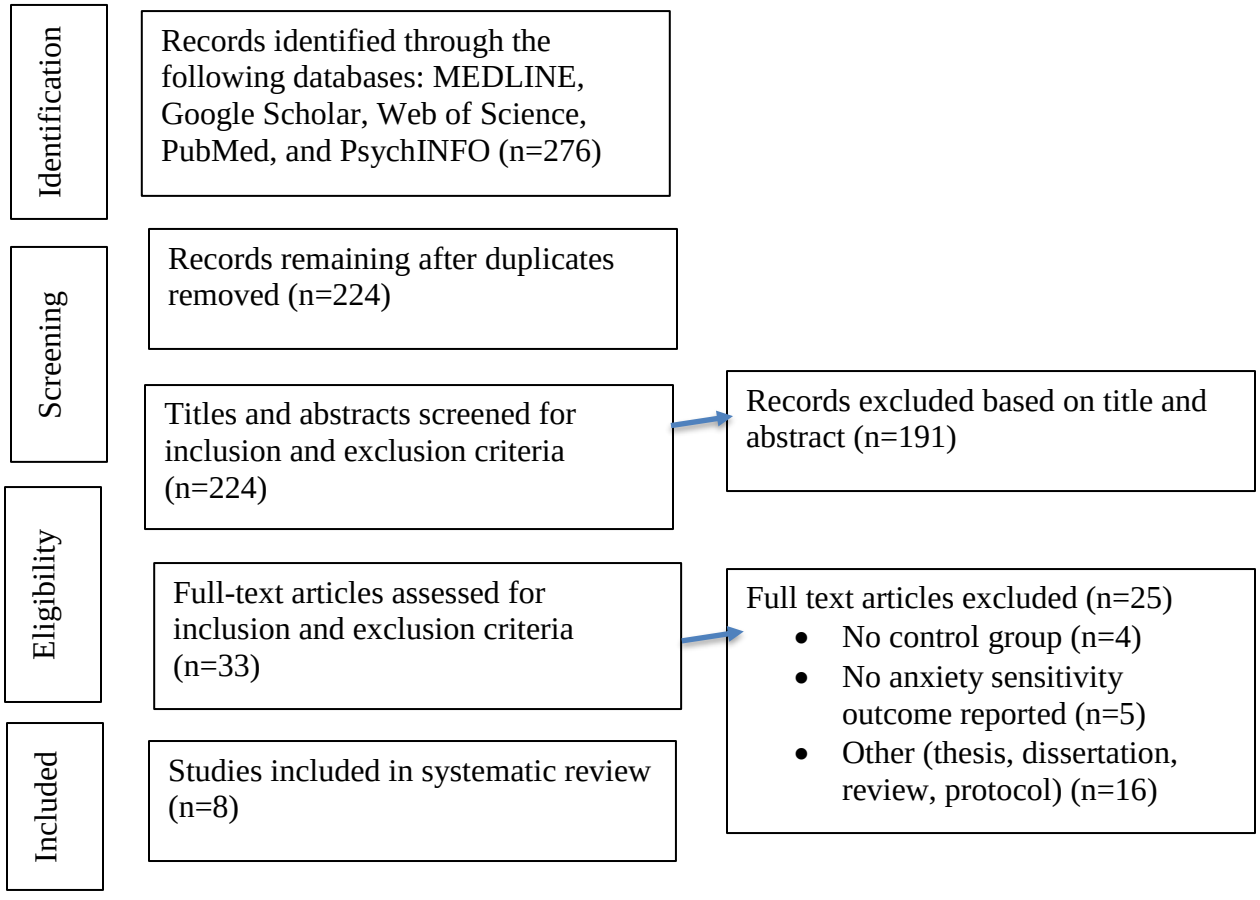

Figure 1. PRIMSA Consort

Characteristics of included trials and participants. Across the eight included studies, seven included mixed-gender (male and female) samples. All studies included a control group; two included a resistance-training control group, while three included a moderate-intensity exercise control group. The average age ranged from 18.75-35.3 years. Intensity of exercise ranged from "low" (control) to "high" or "vigorous" (60-90% max HR). Specific characteristics can be found below for studies examining the impact of acute (Table 1) and chronic (Table 2) exercise on AS.

Table 1

Summary characteristics for included studies that measured the effects of acute exercise on anxiety sensitivity

Study	Year	Condition	Control?	N	Gender	Age (M)	AS Measure	Intensity	Type
Broman-Fulks et al.	2015	Intervention: Aerobic	Yes	25	9 male, 16 female	20.12	ASI-3	65-75% max HR (moderate)	Aerobic
		Intervention: Resistance		26	10 male, 16 female	19.19			Resistance Training
		Control (Rest)		26	12 male, 14 female	19.74			Sit
LeBouthillier & Asmundson	2015	Intervention	Yes	21	10 male, 11 female	35.33	ASI-3	60-80% max HR (vigorous)	Aerobic
		Control		19	6 male, 13 female	30.95		HR < 50% max	Stretching
Mason & Asmundson	2018	Intervention: Sprint Interval	Yes	16	2 male, 14 female	22.81	ASI-3	85% age-adjusted HR max	Aerobic (Cycle Sprints)
		Intervention: Continuous Training		20	4 male, 16 female	27.75		70% age adjusted HR max	Aerobic (Cycling)
		Waitlist Control		20	5 male, 15 female	23.34			Waitlist

Table 2

Summary characteristics for included studies that measured the effects of chronic exercise on anxiety sensitivity

Study	Year	Condition	Control?	N	Gender	Age (M)	AS Measure	Frequency	Intensity	Type
Broman-Fulks et al.	2004	Intervention: Aerobic	Yes	29	6 male, 23 female	20.76	ASI	2-4x/week, total 6 sessions, across 2 weeks	60-90 max HR (high)	Aerobic
		Control: Low intensity walking		25	7 male, 18 female	21.64		2-4x/week, total 6 sessions, across 2 weeks	HR < 60%	Walking
Broman-Fulks & Storey	2008	Intervention	Yes	12	3 male, 9 female	19.33	ASI-R	6 times	60-90% max HR	Aerobic
		Control: Low intensity, non-aerobic activity		12	2 male, 10 female	18.75		6 times		Non-aerobic
LeBouthillier & Asmundson	2017	Intervention: Aerobic	Yes	23	7 male, 16 female	33	ASI-3	3x/week for 4 weeks	60-80% max HR	Aerobic (Cycle)
		Intervention: Resistance		18	3 male, 15 female	31.39		3x/week for 4 weeks		Resistance
		Waitlist control		15	3 male, 12 female	33.4				Waitlist
Sabourin et al.	2016	Intervention: High AS, CBT, Exercise	Yes	34	All female	18.8	ASI	Three 1-hour group sessions + 42 10-minute runs	Not reported	Aerobic
		Intervention: Low AS, CBT, Exercise		29	All female	18.8		Three 1-hour group sessions + 42 10-minute runs		Aerobic
		Control: High AS, Health Education		33	All female	18.8		Three 1-hour HEC group + interactive discussion		Health Education
		Control: Low AS, Health Education		29	All female	18.8		3 1-hour HEC group + interactive discussion		Health Education
Smits et al.	2008	Intervention: Exercise	Yes	19	2 male, 17 female	19.53	ASI	3 sessions/week for 2 weeks	70% max HR	Aerobic
		Intervention: Exercise & Cognitive Restructuring		21	6 male, 15 female	19.86		3 sessions/week for 2 weeks	70% max HR	Aerobic
		Waitlist control		20	7 male, 13 female	22.65			HR < 60%	Waitlist

Effects of acute and chronic exercise on anxiety sensitivity. Across the eight studies, we found a mean ES of 0.52 for acute exercise effects on reducing ASI and a mean ES of 0.86 for studies using chronic exercise to reduce ASI symptoms. Overall, the effects of acute exercise were primarily consistent across different modes of exercise toward reducing ASI (range; 0.30-0.70). A larger range of mean ES was observed for studies utilizing chronic protocols (range; -0.20-2.50). The overall mean ES for all included studies was 0.70, indicating a large ES for exercise in reducing ASI.

Chapter IV

Discussion

Anxiety and its related disorders have been researched and examined extensively, prompting need and desire for examination of effective treatments. Anxiety sensitivity (AS), or an individual's fear of anxiety or arousal-related physical sensations, may be a specific vulnerability factor for many of the DSM-5 anxiety disorders, including posttraumatic stress disorder (PTSD) and obsessive-compulsive disorder (OCD). Given the important role that AS may have in fueling many of the increasingly prevalent DSM-5 anxiety disorders, there is growing emphasis on treatments targeted at reducing AS, specifically those that can reach a wide population range at minimal-to-no cost. AS has been considered a promising transdiagnostic target of treatment for panic disorder, specific phobia, and social anxiety disorder, along with PTSD and OCD. Interventions shown to reduce anxiety sensitivity include psychoeducation, cognitive restructuring, and interoceptive exposure. Due to its relative accessibility, minimal adverse side effects, and potential minimal cost, exercise or physical activity may be an effective approach for targeting anxiety sensitivity, therefore playing a role in prevention and treatment of anxiety.

Several randomized controlled trials thus far have examined the impact that aerobic exercise as well as resistance training may have in reducing AS. Our inclusive search strategy yielded 276 studies, of which eight were included in the analysis. These eight studies were separated by nature of the intervention: chronic and acute. Furthermore, analysis was completed based on type of intervention (aerobic exercise, resistance training, and control). Results from three studies within this meta-analysis yielded a significant medium effect size of exercise for reducing AS and results from five studies yielded significant and large effect sizes for reducing

AS. The empirical evidence reviewed here supports exercise as a potential behavioral treatment for targeting AS. Future research should compare different modes of exercise (aerobic vs. resistance training) to other empirically-supported therapies for anxiety, examine plausible neurobiological mechanisms, and examine exercise and AS within the context of critical patient populations (e.g., cardiac cancer, substance use disorders). In summary, this literature review and meta-analysis of randomized controlled trials offers support for the efficacy of both aerobic exercise and resistance training in reducing AS.

Extended Qualitative Review

CBT has been shown to effectively reduce AS through the use of exposure therapy, in order to help individuals confront their fears to overcome distress. More specifically, CBT for AS utilizes interoceptive exposure by exposing individuals to feared physical sensations. Interoceptive exposure has been shown to be effective in treating AS, as therapy involves habituation to the previously feared sensations, which can potentially lead to extinction. While CBT can reduce symptoms of AS in individuals with anxiety-related disorders, there are several barriers, including lack of accessibility and available to therapists, as well as cost. These barriers may subsequently inhibit the number of people receiving treatment, and, as a result, alternative treatments for AS have been studied.

Aerobic exercise has been the focus of recent investigation surrounding AS treatment due to the fact that it is relatively easy to perform, accessible, and fairly cheap, if not free (e.g., running). Furthermore, exercise does not induce the negative side effects that may occur as a result of pharmacologic treatment, such as selective serotonin reuptake inhibitors (SSRIs). With relation to AS, accruing evidence has shown that aerobic exercise may be effective in reducing AS, as many of the physical sensations stimulated by exercise are similar to those activated during an individual's fear of anxiety-related symptoms. As a result, aerobic exercise may be used as a form of interoceptive exposure therapy, in that individuals experience exercise-induced elevations in heart rate, arousal, respiration, and perspiration. As exercise induces the same physiological sensations associated with anxiety, but in a safe, non-catastrophic manner, it is expected that it reduce AS. As a result, new associations may form between anxious-related bodily sensations and their consequences. The evidence supporting the effects of exercise on AS

and limitations of current literature are discussed below. Suggestions for future research are also considered.

Broman-Fulks and colleagues (2004) performed a study investigating the effects of aerobic exercise on AS. In this study, they randomized participants into either a high-intensity or low-intensity aerobic exercise condition performed over a time span of two weeks. It was found that both groups experienced a decrease in AS. As the low-intensity exercise was also found effective, it is difficult to draw decisive conclusions about the efficacy of exercise in reducing AS, as these results do not rule out the possibility of regression to the mean. However, greater pre-to-post treatment reductions in AS were found for the high-intensity group, suggesting a potential dose-response relation between AS and exercise. In a follow-up study, it was found that exercise led to significant reductions in AS, which were predominantly driven by large treatment effects after the first exercise session. Furthermore, these findings were maintained at follow-up, suggesting exercise has an influence on decreasing AS. In this study, the absence of an attention-control group that would account for demand characteristics may in part explain some of the large effects found between the exercise and no-exercise condition. Nonetheless, these studies established initial evidence supporting the beneficial role of exercise in reducing AS.

Utilizing a similar protocol of exercise, Smits and colleagues (2008) assessed the role of aerobic exercise on AS within a two-week time frame. In this study, there were three conditions: exercise, exercise with a cognitive restricting component, and waitlist control. In comparison to the waitlist control condition, the two conditions that included exercise resulted in AS reductions similar to one another. Furthermore, there were no group differences between the exercise and exercise plus cognitive restructuring groups, suggesting that there was no added benefit of the cognitive restructuring component. Findings of this study also indicated that changes in AS

significantly mediated the effects of exercise on changes in symptoms of anxiety and depression, which both decreased after the intervention. This suggests, AS is an underlying mechanism of the antidepressant and anti-anxiolytic effects of aerobic exercise. A study performed by Medina et al. (2014) aimed to determine whether the relationship between exercise and AS is sexually dimorphic. However, the impacts of aerobic exercise on AS was similar across genders, while the initial and mid-treatment effects were larger for males relative to females. This implies that gender may be a potential moderator of the exercise-AS relationship, warranting further research to determine who benefits the most from an exercise intervention.

Three additional studies assessed the impact of exercise on AS in relation to mood and anxiety disorders. Sabourin et al. (2016) asked female participants to engage in a self-guided running program to evoke physiological arousal following a brief group CBT intervention. The running session was effective in reducing AS in those who were identified as having high AS, while those who were considered to have low AS did not experience any benefits. This supports the notion that exercise may benefit females with high levels of AS; similar effects may not be seen in those with low AS levels. A second study (LeBouthillier & Asmundson, 2015) examined the efficacy of a single bout of exercise in reducing AS, as well the role of exercise in improving other transdiagnostic variables, such as distress intolerance and intolerance of uncertainty. Participants were randomly assigned to either a moderate-intensity aerobic exercise or light stretching condition. It would found that in comparison to stretching, exercise resulted in pre-to-post treatment reductions in AS, while distress intolerance and intolerance of uncertainty were unaffected. At follow-up, participants'' AS levels returned to baseline, suggesting that the effects of a single bout of aerobic exercise on AS are short-lived. Lastly, Broman-Fulks and colleagues (2015) examined other exercise modalities. They randomly assigned participants to either a 20-

minute bout of aerobic exercise, resistance training, or rest control condition. Aerobic exercise and resistance training groups resulted in significant reductions in AS, supporting the use of other exercise modes for reducing AS. In this study, participants were also exposed to a CO2 inhalation stressor task known for producing anxious symptoms. Participants in the aerobic exercise and resistance training groups demonstrated reduced reactivity to the CO2 inhalation compared to participants in the control condition. Reduced reactivity was greatest for those in the aerobic exercise condition.

Collectively, research to date has demonstrated the effectiveness of aerobic exercise for individuals identified as at-risk for the development of an affective disorder (e.g., individuals with high AS levels). Across studies, the most consistent finding is the reduction in AS following exercise, regardless of the control group used in each study. In those studies that utilized multiple exercise sessions, the effects on AS were noticeably larger relative to only using a single bout of exercise. Furthermore, research has suggested that the relationship is intensity-driven, with higher intensity exercise resulting in the greatest benefits. From a practical standpoint, this is understandable, given that higher intensity exercise results in greater physiological arousal, therefore providing sufficient exposure to the feared anxiety-related sensations experienced in those with high levels of AS. Future research should explore other exercise-related variables, such as mode, intensity, frequency, and duration that result in optimal benefits.

While evidence supports the relationship between exercise and AS, several limitations exist. All studies included non-clinical, relatively homogenous (mostly Caucasian females) samples. This subsequently limits overall generalizability. Future investigations should explore the relationship with AS and exercise within clinical populations, as AS amplifies the presence of diagnosed psychopathology. Additionally, future research should include more heterogeneous

samples to assess potential individual differences (e.g., gender, age, ethnicity, socioeconomic status) as well as larger proportion of males to explore possible sexual dimorphic effects. Most studies also used short follow-up periods (usually one week) to examine the lasting effects of exercise on changes in AS levels. During this time period between post-treatment and follow-up, physical activity and/or engagement in exercise were not controlled for. As a result, it is difficult to make definitive conclusions surrounding the nature of the long-term effects of a relatively short exercise program on AS without longer follow-up periods. Future research should assess AS levels at later follow-ups (e.g., 6 months post-intervention) in order to determine time course effects of exercise on AS. This information may be helpful in determining whether short-term reductions in AS are predictive of changes in symptoms (e.g., depression or anxiety) over time. Lastly, as adherence to an exercise program is problematic, research should determine barriers to exercise in mental health populations. Evolving evidence has shown that individuals with greater BMI, higher levels of AS, and lower levels of aerobic fitness, are less likely to engage in exercise on their own. These individuals are at the highest risk for developing psychopathology and the least likely to engage in and adhere to exercise. Consequently, it is important to examine barriers to exercise in at-risk and mental health populations in order to inform treatment options and offer approaches that can be used to increase exercise behaviors.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: Author.

Asmundson, G. J. G., Fetzner, M. G., DeBoer, L. B., Powers, M. B., Otto, M. W., & Smits, J. A. J. (2013). Let's get physical: A contemporary review of the anxiolytic effects of exercise for anxiety and its disorders. *Depression and Anxiety, 30,* 362-373.

Bartley, C. A., Hay, M., & Bloch, M. H. (2013). Meta-analysis: Aerobic exercise for the treatment of anxiety disorders. *Progress in Neuro-Psychopharmacology & Biological Psychiatry, 45,* 34-39.

Broman-Fulks, J. J., Berman, M. E., Rabian, B. A., & Webster, M. J. (2004). Effects of aerobic exercise on anxiety sensitivity. *Behaviour Research and Therapy, 42,* 125-136.

Broman-Fulks, J. J., Kelso, K., & Zawilinski, L. (2015). Effects of a single bout of aerobic exercise versus resistance training on cognitive vulnerabilities for anxiety disorders. *Cognitive Behaviour Therapy, 44*(4), 240-251.

Broman-Fulks, J. J., & Storey, K. M. (2008). Evaluation of a brief aerobic exercise intervention for high anxiety sensitivity. *Anxiety, Stress, & Coping, 21*(2), 117-128.

Chambless, D. L., & Goldstein, A. J. (1981). Clinical treatment of agoraphobia. In M. Mavissakalian & D. H. Barlow (Eds.), *Phobia: Psychological and pharmacological treatment* (pp. 103-144). New York, NY: Guilford Press.

Herring, M. P., O'Connor, P. J., & Dishman, R. K. (2010). The effect of exercise training on anxiety symptoms among patients: A systematic review. *Archives of Internal Medicine, 170*(4), 321-331.

LeBouthillier, D. M., & Asmundson, G. J. G. (2015). A single bout of aerobic exercise reduces anxiety sensitivity but not intolerance of uncertainty or distress tolerance: A randomized controlled trial. *Cognitive Behaviour Therapy, 44*(4), 252-263.

LeDoux, J. (2015). *Anxious: Using the brain to understand and treat fear and anxiety.* New York, NY: Penguin Random House.

Medina, J. L., DeBoer, L. B., Davis, M. L., Rosenfield, D., Powers, M., Otto, M. W., & Smits, J. A. (2014). Gender moderates the effect of exercise on anxiety sensitivity. *Mental Health and Physical Activity, 7,* 147-151.

Olatunji, B. O., & Wolitzky-Taylor, K. B. (2009). Anxiety sensitivity and the anxiety disorders: A meta-analytic review and synthesis. *Psychological Bulletin, 135*(6), 974-999.

Orwin, A. (1974). Treatment of a situational phobia: A case for running. *The British Journal of Psychiatry, 125*, 95-98.

Petruzzello, S., Landers, D., Hatfield, B., Kubitz, K., & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise. *Sports Medicine, 11*(3), 143-182.

Petruzzello, S. J. (2012). The ultimate tranquilizer? Exercise and its influence on anxiety. In E. O. Acevedo (Ed.), *The Oxford Handbook of Exercise Psychology* (pp. 37-54). New York, NY: Oxford University Press.

Powers, M. B., Asmundson, G. J. G., & Smits, J. A. J. (2015). Exercise for mood and anxiety disorders: The state-of-the-science. *Cognitive Behaviour Therapy, 44*(4), 237-239.

Raglin, J. S. (1997). Anxiolytic effects of physical activity. In W. P. Morgan (Ed.), *Physical activity and mental health* (pp. 107-126). Washington, DC: Taylor and Francis.

Sabourin, B. C., Stewart, S. H., Watt, M. C., & Krigolson, O. E. (2016). Two interventions decrease anxiety sensitivity among high anxiety sensitive women: Could physical exercise be the key? *Journal of Cognitive Psychotherapy: An International Quarterly, 30*(2), 131-146.

Sabourin, B. C., Watt, M. C., Krigolson, O. E., & Stewart, S. H. (2015). Running as interoceptive exposure for decreasing anxiety sensitivity: Replication and extension. *Cognitive Behaviour Therapy, 44*(4), 264-274.

Smits, J. A. A., Berry, A. C., Rosenfield, D., Powers, M. B., Behar, E., & Otto, M. W. (2008). Reducing anxiety sensitivity with exercise. *Depression and Anxiety, 25*, 689-699.

Smits, J. A. J., Berry, A. C., Tart, C. D., & Powers, M. B. (2008). The efficacy of cognitive-behavioral interventions for reducing anxiety sensitivity: A meta-analytic review. *Behaviour Research and Therapy, 46*(9), 1047-1054.

Smits, J. A., Zvolensky, M. J., Davis, M. L., Rosenfield, D., Marcus, B. H., Church, T. S. … Baird, S. O. (2016). The efficacy of vigorous-intensity exercise as an aid to smoking cessation in adults with high anxiety sensitivity: A randomized control trial. *Psychosomatic Medicine, 78*, 354-364.

Stein, M. B., & Craske, M. G. (2017). Treating anxiety in 2017: Optimizing care to improve outcomes. *JAMA, 318*(3), 235-236.

Stonerock, G. L., Hoffman, B. M., Smith, P. J., Blumenthal, J. A. (2015). Exercise as treatment for anxiety: Systematic review and analysis. *Annals of Behavioral Medicine*, *49*(4), 542-556.

Stubbs, B., Vancampfort, D., Rosenbaum, S., Firth, J., Cosco, T., Veronese, N., … Schuch, F. B. (2017). An examination of the anxiolytic effects of exercise for people with anxiety and stress-related disorders: A meta-analysis. *Psychiatry Research, 249,* 102-108.

U.S. Department of Health and Human Services. (1999). *Mental health: A report of the Surgeon Genral.* Rockville, MD: U.S. Department of Health and Human Services, Substance Abuse and Mental Health Services Administration, Center for Mental Health Services, National Institues of Health, national Institue of Mental Health.