ANXIETY SENSITIVITY: AN EXAMINATION OF ITS RELATIONS TO PHYSICAL ACTIVITY AND TRANSDIAGNOSTIC ATHLETE MENTAL HEALTH

by

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ABSTRACT

There is a growing body of research that examines anxiety sensitivity (i.e., fear of arousal-based sensations) and physical activity. This research has tended to show that individuals with higher levels of anxiety sensitivity engage in lower levels of physical activity. This relationship has important mental and physical health implications as both anxiety sensitivity and physical activity are associated with numerous health outcomes. Broadly, the purpose of this dissertation is to add to our understanding of the anxiety sensitivity–physical activity relationship. This dissertation achieves this aim across three studies. In Study 1, a meta-analysis was conducted to provide the best estimate of the magnitude of this relationship, given previous studies have reported mixed results. The meta-analysis of 43 studies showed that there is a significant and small inverse relationship between anxiety sensitivity and physical activity across the available literature. With Study 1 suggesting that anxiety sensitivity is a barrier to physical activity participation, Study 2 sought to determine if anxiety sensitivity may explain the concerning gender gap in physical activity levels. The results of Study 2 indicated that anxiety sensitivity is a partial contributor to gender differences in physical activity levels. With Study 1 and Study 2 establishing relationships between anxiety sensitivity and physical activity, Study 3 sought to determine if the transdiagnostic properties of anxiety sensitivity exist in a highly physically active sample of athletes. The results of this Study 3 suggest that anxiety sensitivity is a predictor of a variety of emotional disorder symptoms in athletes including symptoms of anxiety and depression. Overall, this series of studies adds to our understanding of the anxiety sensitivity–physical activity literature by clarifying the magnitude of this relationship, showing how anxiety sensitivity contributes to gaps in physical activity levels between gender groups, and indicating that the transdiagnostic properties of anxiety sensitivity persist in a highly physically active group of athletes.

LIST OF SYMBOLS AND ABBREVIATIONS USED

3-DPAR	3-Day Physical Activity Recall
6MWT	6-minute Walk Test
AHBF	Affect and Health Behaviour Framework
AQ	Actimètre Questionnaire
AS	Anxiety sensitivity
ASI	Anxiety Sensitivity Index
ASI–3	Anxiety Sensitivity Index – 3
B	Beta
BFI	Big Five Inventory
BFI-S	GSOEP Big Five Inventory
BMI	Body mass index
BSA-F	Physical Activity, Exercise, and Sport Questionnaire
CASI	Childhood Anxiety Sensitivity Index
CBT	Cognitive behavioural therapy
CI	Confidence interval
Corr *N*	Number of participants used in correlation analyses
d	Cohen's *d* effect size
df	Degrees of freedom
DSM-IV-TR	Diagnostic and Statistical Manual of Mental Disorders, fourth edition, text revision
EHQ-R	Exercise Habits Questionnaire-Revised
EHS	Exercise Health Survey

EIB	Exercise-induced bronchoconstriction
EPSI	Eating Pathology Symptoms Inventory
ESQ	Exercise Sensitivity Questionnaire
f^2	Cohen's f^2
FLQ	Fantastic Lifestyle Questionnaire
GLTEQ	Godin Leisure-Time Exercise Questionnaire
GAD-7	Generalized Anxiety Disorder - 7
GAD-D	Generalized Anxiety Disorder Dimensional Scale
GPAQ	Global Physical Activity Questionnaire
GSOEP	German Socio-Economic Panel Study
HHQ	Health Habits Questionnaire
HPAPQ	Healthy Physical Activity Participation Questionnaire
I^2	Percentage of heterogeneity attributable to heterogeneity
IPAQ	International Physical Activity Questionnaire
IPAQ-SF	International Physical Activity Questionnaire-Short Form
k	Number of studies
k^{TF}	Number of imputed studies as part of "trim and fill" method
M	Mean
MH	Mental health
MINI-SPIN	Mini-Social Phobia Inventory
N	Sample size
n	Sample size
N/A	Not applicable

NEO-PI-R	NEO Personality Inventory Revised
NR	Not reported
OFT	Open field test
p	*p*-value
PA	Physical activity
PACER	Progressive aerobic cardiovascular endurance run
PAM	Physical Activity Measure
PAQ-IV	Panic Attack Questionnaire-IV
PH	Physical health
PHQ	Patient Health Questionnaire
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
Q_T	Total heterogeneity of weighted mean effects
r	Bivariate correlation
R^2_{analog}	Proportion of variance explained by predictors
r_s	Spearman rank correlation
SD	Standard deviation
SE	Standard error
SPSS	Statistical Packages for the Social Sciences
Sr^2	Squared semi-partial correlation coefficient
t	t-statistic
TLFB-E	Timeline Followback-Exercise
US	United States
USD	United States of America dollars

Wald	Wald chi-square value
WHO	World Health Organization
Z	*Z* score
β	Beta
Δ	Delta
χ2	Chi-square

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CHAPTER 1. INTRODUCTION

Physical Activity

Physical Activity Definition

According to Caspersen et al. (1985), physical activity is any bodily movement produced by skeletal muscles that results in energy expenditure. Physical activity can take all sorts of forms, from a casual walk through the park to running a marathon at the Olympic Games. Physical activity is closely linked with exercise and, colloquially, the two terms are often used interchangeably. However, although all exercise is physical activity, not all physical activity is exercise. Exercise is deliberate physical activity with an intention to improve physical fitness (Caspersen et al., 1985). For example, an individual who mows their lawn when it needs to be cut is engaging in physical activity, but this may or may not be considered exercise depending on if it involved a deliberate intention to improve physical fitness. Alternatively, an individual who goes for a run to improve their health is exercising. Physical activity can be further specified into types. One important classification is leisure time physical activity, which is physical activity that occurs during a person's free time. For example, a carpenter may engage in a great deal of physical activity during their physically demanding workday, but they may not engage in a high level of leisure time physical activity, which occurs outside of their workday (Steinbach & Graf, 2008).

Physical activity is often categorized by intensity. According to the definition provided on the International Physical Activity Questionnaire-Short Form (IPAQ-SF; Craig et al., 2003; Lee et al., 2011), moderate intensity physical activity is activity requiring moderate physical effort that increases breathing to a level somewhat harder than normal. Examples provided in the IPAQ-SF include doubles tennis, carrying light loads, and bicycling at a regular pace. In contrast,

vigorous intensity physical activity is activity requiring hard physical effort that increases breathing to a level much harder than normal. Examples provided in the IPAQ-SF include heavy lifting, aerobics, or fast cycling. The Centers for Disease Control and Prevention (2022) provides a similar categorization of physical activity, defining moderate intensity physical activity as physical activity during which someone can talk but not sing and vigorous intensity physical activity as physical activity during which it is difficult to say more than a few words without pausing for a breath.

Physical Activity Participation

Various organizations recommend how much physical activity individuals should engage in to receive associated health benefits. The World Health Organization (WHO; 2022) recommends that 18–64 year-olds engage in at least 150 minutes of moderate-intensity physical activity or 75 minutes of vigorous-intensity physical activity weekly (or an equivalent combination of the two). The WHO also recommends engaging in strength training that involves all major muscle groups at least twice a week and that sedentary behaviour (i.e., non-movement time) should be limited. Concerningly, the WHO (2022) reports that more than 25% of the world's adults do not engage in sufficient levels of physical activity to remain healthy. Other research suggests global physical inactivity rates of 31% when defining inactivity as engaging in less than 30 minutes of moderate-intensity physical activity at least five days every week, not engaging in 20 minutes of vigorous-intensity physical activity at least three days every week, or an equivalent combination achieving 600 metabolic equivalent minutes per week (Hallal et al., 2012). Adding to this concern, global physical activity levels have not been improving; the percentage of people who meet minimum physical activity recommendations has been decreasing in high-income countries from 2001 to 2015 (WHO, 2022). Additionally, the recent

COVID-19 pandemic has been associated with lowered levels of physical activity worldwide relative to pre-pandemic times (Wunsch et al., 2022).

In Canada, the current physical activity recommendation for adults is to accumulate 150 minutes of moderate to vigorous intensity physical activity weekly (Canadian Society for Exercise Physiology, 2021; Statistics Canada, 2021). Concerningly, less than half (49.2%) of all Canadian adults are meeting this minimum criterion (Statistics Canada, 2021). Many changes in the way the world operates likely contribute to a more sedentary lifestyle. For example, research has shown that physical activity has reduced in a variety of domains including occupational physical activity, transportation-related physical activity, and physical activity in the home, alongside increases in sedentary time (Brownson et al., 2005). Canadians also reported engaging in lower levels of physical activity since the COVID-19 pandemic (Bertrand et al., 2021; Rhodes et al., 2020). Data from Statistics Canada shows that on average, Canadians who work full-time spend 68.9% of their day sedentary (Prince et al., 2020). The poor rates of physical activity in Canada have significant financial impacts. In 2009, the estimated health care costs, both direct (e.g., costs associated with goods and services) and indirect (e.g., costs associated with economic loss from illness) associated with physical inactivity (e.g., portion of costs for treatment for coronary artery disease), were $6.8 billion (Janssen, 2012).

There are many factors that appear to impact physical activity levels. Garcia et al. (2022) recently conducted a review of reviews on the barriers and facilitators of physical activity during leisure, travel, and work or education. Their review included intrapersonal factors (e.g., beliefs, motivation), social/interpersonal factors (e.g., social support), environment factors (e.g., road safety), and programming factors (e.g., quality of instructors). For leisure based physical activity, factors such as motivation and having goals, positive beliefs about consequences, and social

support were shown to have strong evidence as facilitators to physical activity. Lack of time, negative emotions, and poorer health condition were supported as barriers to leisure time physical activity. For travel based physical activity, positive beliefs about consequences, walkability, and having facilities in place (e.g., play parks) were some of the most supported facilitators. There were no factors consistently shown to be barriers to travel-based physical activity. Finally, for work or education based physical activity, none of the variables assessed appeared to have strong support for impacting physical activity levels.

Physical Activity and Health

Physical activity is undoubtedly beneficial for many aspects of physical health. The WHO (2022) reports that physical inactivity is one of the greatest risk factors for noncommunicable diseases and it increases mortality risk by 20 to 30 percent. Physical activity reduces the risk for many significant health concerns including cardiovascular disease, diabetes, some cancers, and osteoporosis (Warburton et al., 2006). Physical activity is associated with reduced rates of obesity and there is some evidence of it being associated with lower rates of Alzheimer's and other forms of dementia (Reiner et al., 2013). There are at least 40 health-related conditions that worsen for individuals who live a physically inactive lifestyle (Ruegsegger & Booth, 2018).

The many health benefits of physical activity include not only physical health, but also mental health. In a cross-sectional study involving 1.2 million American adults (Chekroud et al., 2018), individuals who reported engaging in exercise in the past month had significantly fewer number of self-reported poor mental health days in the past month compared to those who did not report any past-month exercise. The same study showed that engaging in physical activity in the past month accounted for a larger decrease in self-reported mental health symptoms than

other well-known risk factors such as education and income. Interestingly, the researchers also found that more physical activity is not always better. Their results revealed a U-shape pattern where individuals who exercised three to five times per week had lower mental health burden than those engaging in physical activity less than three days per week as well as those who engaged in physical activity more than five times per week. In another study of almost 20,000 individuals (Hamer et al., 2009), physical activity (measured as frequency of bouts >20minutes) was associated with significantly lower levels of psychological distress after accounting for several demographic and lifestyle factors (e.g., socio-economic status, body mass index). This was true when examining all activity sessions, sport participation sessions, walking sessions, and domestic activities (e.g., gardening). The study also found a dose-response relationship for all activities and sports activities where minimal levels of physical activity (i.e., 1-3 20-minute bouts per week) were beneficial for reducing psychological distress and the benefits increased with greater physical activity intensity and/or duration. Exercise has also been associated with improved cognitive functioning and wellbeing (for a review, see Mandolesi et al., 2018). Individuals who do not engage in physical activity are more likely to exhibit symptoms of both depression and anxiety (De Mello et al., 2013).

Research has shown that individuals with certain mental health diagnoses engage in lower levels of physical activity than those without a mental health diagnosis. In a sample of individuals with serious mental illness (i.e., schizophrenia and affective disorders), Daumit et al. (2005) found that these individuals engaged in significantly lower levels of physical activity when compared to a national sample matched on age, gender, and race. Within this sample, being a woman and having less social contact was also associated with lower physical activity levels (Daumit et al., 2005). In populations with severe mental illness, fatigue and illness are

commonly reported barriers to exercise, despite these individuals believing that engaging in physical activity is beneficial (Ussher et al., 2007). Meta-analytic results indicate that individuals with major depressive disorder engage in less total physical activity, less moderate to vigorous physical activity, are less likely to meet physical activity recommendations, and engage in higher levels of sedentary behaviour than those without major depressive disorder (Schuch et al., 2017). In a nationally representative sample in the United States (Goodwin, 2003), those who reported "regularly" engaging in physical exercise (versus those who reported engaging in physical exercise "never", "occasionally" or "rarely") had significantly reduced prevalence of major depression, panic attacks, social anxiety disorder, specific phobia, and agoraphobia. No significant differences between those reporting regular physical activity and those who reported less frequent physical activity (i.e., reported engaging in physical exercise "never", "occasionally" or "rarely") were found in the prevalence of generalized anxiety disorder, bipolar disorder, dysthymia, alcohol dependence, or substance dependence. This pattern of results emerged after controlling for comorbid diagnoses and socio-demographic variables suggesting a specific link between physical activity and reduced risk for most emotional disorders (i.e., anxiety-related disorders and depression). Indeed, meta-analytic results synthesizing prospective cohort studies show that physical activity can be a protective factor for the development of major depressive disorder (Schuch et al., 2018) and anxiety disorders, particularly agoraphobia and post-traumatic stress disorder (Schuch et al., 2019). Evidently there is a large body of research to support an association between physical activity and mental health, particularly emotional health.

Not only is there an association between physical activity and mental health, but research has also shown that physical activity alone is sufficient to reduce mental health symptoms and lead to diagnostic remission. Much of this research has focused on the impact of physical activity

on improving symptoms of depression. Research has shown that physical activity interventions are effective for treating major depressive disorder across age groups (Ashdown-Franks et al., 2020). There is more evidence to support the use of anaerobic exercise for mood improvements, although there is support for aerobic exercise to improve mood as well (Chan et al., 2019). Meta-analytic results suggest that high intensity interval training can improve depressive symptoms in individuals with major depressive disorder from pre-test to post-test (Martland et al., 2020), although more research using control groups is needed to attribute causality to the exercise.

In their systematic review, Chan et al. (2019) examined the benefits of physical activity for mood while considering intensity, duration, and modality. Regarding intensity, they found that the results were inconclusive, although for anaerobic physical activity, moderate-intensity physical activity appeared to yield greater mood improvements than low-intensity or vigorous-intensity physical activity. Most studies in the review suggested that physical activity can improve mood in as short a duration as 10-15 minutes. As well, more consistent evidence was provided for the benefits of anaerobic physical activity, although aerobic physical activity still has some support (Chan et al., 2019).

Furthermore, there is an accumulation of evidence to suggest that physical activity can reduce anxiety symptoms. In a meta-analysis of individuals with an anxiety disorder or clinically elevated levels of anxiety symptoms, aerobic physical activity significantly reduced anxiety compared to waitlist control. Results suggested that reductions were maintained at longer-term follow up periods. The results also suggested that the effects were greater for high-intensity physical activity compared to low intensity physical activity, and that similar reductions were seen between those with an anxiety disorder compared to those with clinically elevated anxiety

(Aylett et al., 2018). Meta-meta-analytic results also indicate that physical activity can reduce anxiety in non-clinical populations (Rebar et al., 2015).

Physical activity can lead to benefits beyond mood and anxiety. It can improve a variety of concerns present in individuals with schizophrenia, including positive and negative symptoms, cognition, and quality of life (Girdler et al., 2019). A recent comprehensive review of lifestyle factors and mental illness indicate that physical activity can be an effective adjunctive treatment for depression, anxiety, and stress-related disorders, psychotic disorders, and attention-deficit hyperactivity disorder (Firth et al., 2020). Exercise has also been shown to improve sleep quality in individuals with mental illness (Lederman et al., 2019).

Taken together, the relationship between physical activity and mental health is complex. Both research examining the relationship between physical activity levels and mental health outcomes and research examining the effects of physical activity on mental health outcomes have demonstrated the importance of engaging in physical activity. Although this is the general trend across the literature, it is important to note that the relationship between physical activity and mental health can be impacted by the physical activity completed, the mental health factors assessed, and individual differences (Asztalos et al., 2010).

Anxiety Sensitivity

Anxiety Sensitivity Definition

Anxiety sensitivity is an established transdiagnostic construct (i.e., risk factor with relevance to multiple mental health problems) that appears to be involved in the relationship between physical activity and mental health. Anxiety sensitivity is a fear of anxiety sensations based on an interpretation that the sensations have significantly negative consequences (Reiss & McNally, 1985). Anxiety sensitivity is distinct from anxiety (Taylor et al., 1991); anxiety is the

experience of physiological, cognitive, and affective symptoms, whereas anxiety sensitivity is the catastrophic interpretation of these symptoms. As such, an individual may experience anxiety (e.g., an elevated heart rate), but not fear that it is an indication of an oncoming heart attack (i.e., low anxiety sensitivity). Anxiety sensitivity involves three subdomains: a physical concerns domain that captures individuals' fear of physical anxiety sensations (e.g., increased heart rate) due to concerns of catastrophic consequences from them (e.g., heart attack), a cognitive concerns domain that captures individuals' fear of cognitive anxiety sensations (e.g., racing thoughts) due to perceived catastrophic consequences from them (e.g., going crazy), and a social concerns domain that captures individuals' fear of publicly-observable anxiety sensations (e.g., sweating in public) due to perceived catastrophic consequences from them (e.g., social ridicule from displaying anxiety). An individual high in anxiety sensitivity physical concerns may experience shortness of breath and interpret this as a sign that they will pass out. An individual high in cognitive concerns may experience their mind going blank and believe they will lose control of their thoughts. An individual high in anxiety sensitivity social concerns may experience sweating in a social setting and believe they will experience intolerable judgment from others (Taylor et al., 2007).

Anxiety sensitivity is a key construct in Reiss' expectancy model of fear, anxiety, and panic (Reiss & McNally, 1985; Reiss, 1991). This model explains the role of anxiety sensitivity in the development of anxiety. It suggests that avoidance of a feared situation/ stimulus is based on both expectancies and sensitivities. For example, if an individual who must give a public speech has a high expectation that they will stumble on their words as well as a sensitivity that others would judge them negatively based on this behaviour, they may avoid the speech. If an individual does not expect the feared event to occur (e.g., no expectation of stumbling on words),

then the situation would not be avoided, even if there is high sensitivity. The same can be said for the case of high expectation and low sensitivity (e.g., expecting to stumble on words but thinking it is no big deal to do so).

Anxiety Sensitivity and Mental Health

Anxiety sensitivity is associated with a variety of anxiety and related disorders. Samples with an anxiety disorder have significantly higher anxiety sensitivity than samples with depression and non-clinical controls (Olatunji & Wolitzky-Taylor, 2009). As well, groups with depression have significantly higher anxiety sensitivity than non-clinical controls (see review by Olatunji & Wolitzky-Taylor, 2009). Individuals with post-traumatic stress disorder, generalized anxiety disorder, panic disorder/agoraphobia, social anxiety disorder, obsessive-compulsive disorder, specific phobia, and depression have higher anxiety sensitivity scores than community samples (Naragon-Gainey, 2010). Between diagnostic categories included (i.e., posttraumatic stress disorder, generalized anxiety disorder, panic disorder/agoraphobia, depression, social anxiety disorder, obsessive compulsive disorder, and specific phobia) in a meta-analysis by Naragon-Gainey (2010), individuals with post-traumatic stress disorder, generalized anxiety disorder, and panic disorder/agoraphobia had the highest anxiety sensitivity levels (Naragon-Gainey, 2010).

Longitudinal research has shown that anxiety sensitivity is a prospective predictor of mental health concerns such as anxiety and depression (e.g., Zavos et al., 2012). Anxiety sensitivity subscales also have varied relationships certain mental health outcomes (e.g., cognitive concerns being a particularly salient predictor of subsequent panic; Li & Zinbarg, 2007). According to the expectancy model (Reiss, 1991), anxiety sensitivity puts an individual at risk for panic as their fears of anxiety-related sensations amplify their anxiety and put them at

increased risk for a panic attack. Regarding depression, it has been shown that anxiety sensitivity prospectively predicts depression above and beyond anxiety (Zavos et al., 2012). One suggestion for this finding is that anxiety sensitivity may contribute to depression though shared cognitive features (e.g., rumination; Zavos et al., 2012).

At the same time as anxiety sensitivity predicts subsequent mental health outcomes, anxiety and depression can impact subsequent anxiety sensitivity levels (Zavos et al., 2012). According to the "scar model", experiencing pathology such as anxiety and depression can "scar" an individual and in fact increase vulnerability factors (e.g., anxiety sensitivity; Schmidt et al., 2000). Taken together, empirical results and theory provide support for a bi-directional relationship between anxiety sensitivity and mental health.

In addition to this bi-directional relationship, anxiety sensitivity also appears to be a mechanism involved in mental health symptom improvement following treatment. Research has shown that a reduction in anxiety sensitivity partially mediates reductions in symptoms of agoraphobia, anxiety, and panic following cognitive behavioural therapy for panic disorder and fully mediates changes in functional impairment (Smits et al., 2004). As well, a reduction in anxiety sensitivity has been shown to mediate changes in anxiety symptoms following cognitive behavioural therapy delivered at an outpatient anxiety clinic (Asnaani et al., 2020). Anxiety sensitivity domains also appear to play unique roles in mental health treatment. In a study of cognitive behavioural therapy for depression (Thiruchselvam et al., 2020), higher pre-treatment anxiety sensitivity cognitive concerns were associated with greater symptom improvement towards the end of a 14-week group-based treatment. Interestingly, increased pre-treatment anxiety sensitivity physical concerns were associated with reduced likelihood of completing the treatment.

With established relationships between anxiety sensitivity and mental health, anxiety sensitivity has been examined as a treatment target in the context of clinical researchers' recent focus on the utility of transdiagnostic mental health treatment (i.e., treatment that targets common factors across diagnoses and that can be used to treat multiple disorders; Schaeuffele et al., 2021). In a large study of 9,282 individuals, it was found that approximately 45% of those with a mental health diagnosis had more than a single diagnosis (Kessler et al., 2005). Comorbid diagnoses present challenges to providing manualized treatment focused on a single disorder. Thus, treatments focused on anxiety sensitivity, as one important transdiagnostic risk factor, have the potential to reduce symptoms across comorbidities. Overall, meta-analytic results indicate a moderate to large effect for cognitive behavioural therapy in reducing anxiety sensitivity (Smits, Berry, Tart et al., 2008). Research on the transdiagnostic effects of anxiety sensitivity treatments have also been promising. For instance, studies of single session anxiety sensitivity interventions have resulted in anxiety sensitivity reductions that mediated intervention-related changes in symptoms of anxiety and depression at follow-up (Norr et al., 2014) and in suicide outcomes (Schmidt et al., 2017). Similarly, Olthuis, Watt, Mackinnon et al. (2014) found that a telephone-delivered, cognitive behavioural intervention for anxiety sensitivity was effective in reducing anxiety sensitivity, number of clinical diagnoses, and symptoms of panic, social anxiety, and post-traumatic stress. Mediation analyses suggested that changes in anxiety sensitivity mediated changes in a variety of emotional disorder symptoms (Olthuis, Watt, Mackinnon, et al., 2014). Anxiety sensitivity interventions may also reduce problematic drinking behaviour in adults (Watt et al., 2006; Olthuis et al., 2015) and substance use in youth (see review by Conrod, 2016). Finally, research suggests that targeting anxiety

sensitivity in interventions as a preventative approach may reduce the risk of developing mental illness (Schmidt et al., 2007).

Anxiety Sensitivity and Physical Activity

Relationship Between Anxiety Sensitivity and Physical Activity

As mentioned, Reiss' (1991) expectancy model of fear suggests that situations are avoided when there is an expectation for an event to occur and a belief that the event will have a negative consequence. This theory can help to explain the role of anxiety sensitivity in anxiety and related concerns and may also have implications for physical activity. According to this theory, there should be an inverse relationship between anxiety sensitivity and physical activity. Individuals high in anxiety sensitivity fear catastrophic consequences from anxiety-related sensations and many of these same sensations are brought on by physical activity. For example, high anxiety-sensitive individuals may fear anxiety-related sensations like increased heart rate, breathlessness, and sweating, all of which typically occur during physical activity. If an individual believed a rapid heart rate would cause a heart attack, it would be expected for them to try to avoid experiencing a fast heart rate (e.g., by reducing their physical activity). Indeed, there appears to be an inverse relationship between anxiety sensitivity and physical activity. An early study examining the relationship between anxiety sensitivity and arousal-increasing behaviours, showed that anxiety sensitivity was negatively associated with frequency of exercise and self-rated fitness in men, although this relationship was not found in women (McWilliams & Asmundson, 2001).

Research has replicated the role of sex in the anxiety sensitivity–physical activity relation. In another study (Gomez et al., 2021), anxiety sensitivity was associated with fewer minutes of past-week physical activity levels in men, but there was no difference in physical

activity levels based on anxiety sensitivity for women, replicating McWilliams and Asmundson's (2001) earlier findings. The same study found that anxiety sensitivity was associated with decreased walking time for men but unexpectedly with *increased* walking time for women (Gomez et al., 2021). These two studies suggest that sex may be involved in the anxiety sensitivity–physical activity relationship.

While results from McWilliams and Asmundson (2001) and Gomez et al. (2021) did not show the theoretically expected inverse relationship of anxiety sensitivity and physical activity in women, this relationship has been shown in other studies. In one women-only sample, participants with high (versus low) anxiety sensitivity reported lower monthly duration of physical activity, lower perceived physical fitness, having more barriers to physical activity, and greater perceived benefits to physical activity (Sabourin et al., 2011). Mediation analyses indicated that perceived barriers to physical activity mediated anxiety sensitivity group differences in physical activity levels. This mediation effect, in combination with the high anxiety sensitivity group reporting less physical activity despite perceiving greater benefits, suggests that perceived barriers to physical activity have a strong influence on anxiety-sensitive individuals' low physical activity participation (Sabourin et al., 2011).

In addition to sex, other physical characteristics, such as body mass index or physical health may be involved in moderating the relation between anxiety sensitivity and physical activity. Hearon and colleagues (2014) objectively measured physical activity for five days in a sample with varied anxiety sensitivity and body mass index levels. Few participants in their study completed vigorous-intensity physical activity during the monitoring period, so the researchers focused on moderate-intensity physical activity. There were no significant differences in moderate-intensity physical activity levels based on anxiety sensitivity or body

mass index levels. However, the interaction between anxiety sensitivity and body mass index on physical activity levels was significant. In normal weight individuals, anxiety sensitivity was associated with increased levels of physical activity while in obese individuals, anxiety sensitivity was associated with decreased levels of physical activity. One possibility is that individuals with a high body mass index experience the feared arousal sensations more easily (e.g., shortness of breath from a walk rather than from a run) and thus engage in more avoidance of moderate-intensity physical activity. The positive association found between anxiety sensitivity and physical activity for individuals at a normal weight was unexpected and the researchers suggested that perhaps these individuals engage in more physical activity to positively influence their health and avoid feared negative health outcomes.

Regarding physical health conditions, it would make sense for individuals with physical health conditions, particularly cardiovascular conditions, to have increased fear of, and to catastrophize on, their arousal sensations and as a result, engage in lower levels of physical activity. For example, individuals with a history of a heart attack may be more likely to catastrophize on the meaning of an increased heart rate due to their previous adverse experience of a heart attack. Indeed, patients in cardiac rehabilitation appear to report higher levels of anxiety sensitivity and anxiety sensitivity in this population has been associated with fear of negative consequences from exercise (Farris et al., 2018). In patients with a history of myocardial infarction, those with elevated anxiety sensitivity had 48% greater odds of being physically inactive after controlling for demographic variables and number of myocardial infarctions (Alcántara et al., 2020).

Just as individuals with cardiovascular conditions may have reason to be more fearful of their arousal sensations (due to increased risk of consequences and previous negative

experiences), individuals with good cardiovascular health may have less anxiety sensitivity because they have less risk of negative consequences from arousal and possibly fewer negative experiences with those sensations. This may be particularly true of individuals who engage in high levels of physical activity, given physical activity can reduce anxiety sensitivity (e.g., Olthuis et al., 2020). In one study that examined anxiety sensitivity in athletes (DeWolfe et al., 2022), athletes compared to low active individuals were shown to have significantly lower levels of global anxiety sensitivity as well as of physical concerns and social concerns. Athletes and low active individuals did not significantly differ in cognitive concerns. Overall, this study indicated that anxiety sensitivity tends to be lower in a highly physically active athlete sample.

In a recent study examining physical health conditions and anxiety sensitivity, Connell and Olthuis (2023) investigated the relation between anxiety sensitivity and physical activity in individuals with spinal cord injury. They selected this population due to physiological changes associated with arousal sensations that this population can experience (e.g., differences in sweating). They found, a set of significant positive relations between anxiety sensitivity and physical activity. The researchers assessed physical activity by intensity and separated it into activities of daily living, leisure time physical activity, and total physical activity. Across all physical activity categories assessed, global anxiety sensitivity and anxiety sensitivity physical concerns were significantly and positively associated with moderate intensity activities of daily living and total moderate intensity physical activity. Social concerns shared the same significant and positive relations with the addition of total activities of daily living, which was also positive. For cognitive concerns, only moderate intensity activities of daily living had a significant positive relationship with anxiety sensitivity (Connell & Olthuis, 2023). The researchers explained that a positive relation between anxiety sensitivity and physical activity in individuals

with spinal cord injury may exist due to differences in the experience of physical sensations or increased health-related concerns.

There is also evidence to suggest psychological factors may be involved in the anxiety sensitivity–physical activity relation. In a study of impulsivity and physical activity (in the form of metabolic equivalent of task-minutes per week), Galbraith et al. (2022) found impulsivity to moderate the anxiety sensitivity–physical activity relation, but only for moderate-intensity physical activity. There was no moderation effect for vigorous-intensity physical activity or walking, although a significant inverse relation was present between anxiety sensitivity and vigorous-intensity physical activity. At moderate intensity, a significant inverse relationship between anxiety sensitivity and physical activity was only present at low levels of impulsivity. This anxiety sensitivity–moderate-intensity physical activity relation was not significant at average or high levels of impulsivity. The authors concluded that impulsivity may help prevent individuals with elevated anxiety sensitivity from worrying about future-oriented negative consequences of physical activity, but only when feared sensations are not too intense.

Furthermore, Hearon and Harrison (2021) examined the role of personality factors and anxiety sensitivity in predicting objectively measured physical activity. Stepwise regression results indicated that anxiety sensitivity and agreeableness were significant predictors of percent of time spent engaging in moderate intensity or greater physical activity above and beyond demographics. Increased anxiety sensitivity and agreeableness were both associated with lower physical activity levels. Neuroticism, extraversion, openness to experience, and conscientiousness were non-significant and excluded from the model. This suggests that anxiety sensitivity is a better predictor of physical activity than the Big Five personality domains, except for agreeableness. It also indicated that anxiety sensitivity predicts unique variance in physical

activity levels that are not explained by the Big Five personality factors. Anxiety sensitivity was not a significant predictor of sedentary time.

Not only can individual characteristics influence the relation between anxiety sensitivity and physical activity, but studies also suggest that the way in which researchers measure anxiety sensitivity (e.g., continuously vs. categorically) and physical activity (e.g., low, moderate, or vigorous intensity) may influence the anxiety sensitivity–physical activity association. For example, Moshier and colleagues (2013) found that there was an inverse relationship between anxiety sensitivity and physical activity (measured as metabolic equivalent of task-minutes per week, which includes duration and intensity), but only for vigorous-intensity physical activity. After controlling for sex, this significant relationship was present when examining anxiety sensitivity as a continuous variable. Interestingly, the relationship was also significant when using a cut-off score of 20 (based on a large sample mean; Reiss et al., 2008) on the Anxiety Sensitivity Index (ASI; Peterson & Reiss, 1992) to categorize participants as high or low in anxiety sensitivity, but not when using the clinical cut-off score of 25 (Reiss et al., 2008) to group participants.

Although most research on the relationship between anxiety sensitivity and physical activity has been cross-sectional, Moshier et al. (2016) conducted an interesting study to show that anxiety sensitivity interferes with prospective physical activity participation. In a study of individuals with elevated anxiety sensitivity who were interested in increasing their exercise participation, participants completed baseline measures and set an exercise goal for the following week. One week later, participants reported their accumulated exercise participation. Anxiety sensitivity was not significantly related to the exercise goals that participants set, but it was associated with post-goal physical activity levels. Specifically, anxiety sensitivity predicted

lower post-goal physical activity levels above and beyond baseline physical activity levels while impulsivity, grit, perceived behavioural control, and action planning did not. This study demonstrated that anxiety sensitivity can create barriers to changing physical activity behaviour, even for those who plan to do so (Moshier et al., 2016).

Taken together, the results tend to suggest there is an inverse relation between anxiety sensitivity and physical activity. However, there is variability in this relation across the literature. Physical participant characteristics, psychological participant characteristics, measurement approach, and physical activity intensity all have been shown to be involved in potentially moderating this relation.

Anxiety Sensitivity and Physical Activity in Other Relationships

Several studies have shown that anxiety sensitivity and physical activity are both involved in other relationships. In other words, anxiety sensitivity has relevance for associations between physical activity and other constructs, and vice versa. For example, anxiety sensitivity has been shown to mediate the relationship between physical activity and symptoms of anxiety, depression, and somatization (Broman-Fulks et al., 2018). Specifically, increased exercise may be associated with fewer mental health symptoms in part due to exercise-induced reductions in anxiety sensitivity.

Although there is support for anxiety sensitivity as a mechanism to explain mental health benefits of physical activity (Broman-Fulks et al., 2018), this finding may not apply to all populations. One population where this may not apply is within athlete populations. Athletes engage in elevated amounts of physical activity and have reduced anxiety sensitivity (DeWolfe et al., 2022). Despite their elevated physical activity and lower anxiety sensitivity, research tends to show that athletes have similar rates of mental health concerns as non-athletes (e.g.,

Gorczynski et al., 2017; Rice et al., 2019). Clearly this is an area where more work is needed to understand the relationships between anxiety sensitivity, physical activity, and mental health.

DeBoer et al. (2012) conducted a study to examine relationships among anxiety sensitivity, physical activity, and binge eating. They outlined how: a) binge eating can occur to reduce negative affect; b) anxiety sensitivity is associated with negative affect; and c) how physical activity can be a protective factor against negative affect. Their results indicated that physical activity moderates the relationship between anxiety sensitivity and binge eating. Specifically, anxiety sensitivity was shown to have a positive relationship with binge eating for individuals with low levels of moderate-intensity physical activity and no association for those with higher levels of moderate-intensity physical activity. Interestingly, a different pattern of results emerged when examining vigorous-intensity physical activity. At both high and low levels of vigorous-intensity physical activity, anxiety sensitivity was positively associated with binge eating, although this relationship was stronger at high levels of vigorous-intensity physical activity. This suggests that moderate-intensity physical activity can buffer against the impact of anxiety sensitivity on binge eating. Additionally, the researchers explained that vigorous-intensity physical activity may serve to reinforce binge eating by counteracting potential weight gain associated with binge eating (DeBoer et al., 2012).

Anxiety sensitivity is also involved in the relationship between strenuous physical activity, pain catastrophizing, and pain response. Goodin et al. (2009) outlined research showing that strenuous exercise reduces pain experiences and examined the roles of anxiety sensitivity and pain catastrophizing in this effect. They found that pain catastrophizing mediated the relationship between strenuous exercise and pain responses; however, anxiety sensitivity levels moderated this mediation effect. At high levels of anxiety sensitivity, but not at intermediate or

low levels, pain catastrophizing mediated the relationship between strenuous exercise levels and pain response (Goodin et al., 2009). At high levels of anxiety sensitivity, weekly strenuous exercise bouts were inversely related to pain catastrophizing, which was subsequently positively associated with pain ratings. This suggests that participation in strenuous exercise and anxiety sensitivity work together to influence pain catastrophizing and in turn pain experience.

Anxiety sensitivity and physical activity appear to be involved in individuals' response to carbon dioxide challenges. These challenges involve having participants inhale carbon dioxide enriched gas to simulate panic symptoms in a safe manner. In a non-clinical sample of adults, anxiety sensitivity moderated the relationship between weekly minutes of physical activity and fear ratings in response to a carbon dioxide challenge. For individuals with normative levels of anxiety sensitivity, fear ratings were similar across physical activity levels. For individuals with elevated anxiety sensitivity, fear ratings were significantly lower for individuals with high levels of physical activity (Smits, Tart et al., 2011). In other words, fear of the carbon dioxide challenge was only elevated in those high anxiety-sensitive individuals reporting low levels of physical activity. Other research has shown than an acute bout of physical activity can significantly reduce carbon dioxide challenge fear responses, even after controlling for anxiety sensitivity (Smits et al., 2009). Taken together, these results show that physical activity may serve as a protective factor for individuals high in anxiety sensitivity who are prone to experiencing panic. In line with these findings, Smits and Zvolensky (2006) found that among a sample of individuals with panic disorder, physically active (vs. inactive) participants had lower panic symptom severity and anxiety sensitivity. However, their results indicated that physical activity did not predict panic severity above and beyond anxiety sensitivity. This suggests that

differences in anxiety sensitivity explain the differences in panic symptoms found between the physical activity groups.

In addition, anxiety sensitivity and physical activity have been shown to be involved in smoking behaviours. Cross sectional research (Tart et al, 2010) has shown that vigorous-intensity physical activity is associated with lower amounts of cigarette smoking and that this relationship is mediated by lower negative affect. Adding anxiety sensitivity as a moderator to this mediation effect improves model predictions of smoking behaviour. Specifically, the mediation effect was stronger in individuals with elevated anxiety sensitivity and non-significant at low levels of anxiety sensitivity. This suggests that vigorous physical activity can help reduce smoking by reducing negative affect that may drive smoking behaviour, particularly for those with elevated anxiety sensitivity. Additionally, in a sample of cannabis users, moderate intensity physical activity was shown to have an inverse relation with cannabis coping motives and this relationship was mediated by anxiety sensitivity. This suggests that moderate-intensity physical activity reduces marijuana coping motives through reductions in anxiety sensitivity (Smits, Bonn-Miller et al., 2011)**.**

Experience During Physical Activity

In addition to impacting the frequency, amount, and intensity of participation in physical activity, anxiety sensitivity appears to impact the experience individuals have while engaging in physical activity. For example, anxiety sensitivity is associated with fear during physical activity. In a study by Smits et al. (2010), participants in an experimental condition completed 20 minutes of treadmill exercise at 70% of age predicted heart rate max and rated their subjective units of distress every four minutes. Results revealed an interaction between anxiety sensitivity, measured using the Anxiety Sensitivity Index (Reiss et al., 1986) and body mass index on fear

during physical activity. For participants at a mean level of anxiety sensitivity, there was no change in fear across body mass index groups; for participants above an anxiety sensitivity clinical cut-off value of 25, fear during physical activity increased as body mass index increased. This suggests that distress during physical activity was at its peak among those with high body mass index and high anxiety sensitivity. Perhaps individuals with elevated body mass index experience greater intensity of arousal sensations during physical activity, which interacts with anxiety sensitivity to influence distress during physical activity. Alternatively, perhaps increased body mass strengthens the belief that negative consequences will occur from anxiety-related sensations as increased body mass index is associated with increased health concerns (e.g., cardiovascular disease risk; Gregg et al., 2005).

A similar theme of high anxiety-sensitive individuals experiencing less positive and more negative emotions during physical activity emerged in a study of low-active individuals seeking treatment to reduce smoking. Farris and colleagues (2019) evaluated the role of anxiety sensitivity in affective responses to physical activity and found that anxiety sensitivity was associated with lower enjoyment of physical activity. Their results also indicated that anxiety sensitivity was associated with lower mood and higher anxiety both pre-physical activity and post-physical activity. With both increased fear and reduced enjoyment during physical activity, it is unsurprising that individuals high in anxiety sensitivity engage in lower levels of physical activity.

In addition to impacting affect experienced while exercising, anxiety sensitivity may affect perceptions of the difficulty of physical activity. Farris and colleagues (2017) demonstrated that smokers with differing levels of anxiety sensitivity reported different patterns of perceived exertion during a physical activity task. Participants completed an incremental

submaximal walking task and reported their ratings of perceived exertion during the task. While there was not a significant relationship between ratings of perceived exertion and anxiety sensitivity overall, ratings of perceived exertion tended to stabilize less quickly for individuals high in anxiety sensitivity than for those low in anxiety sensitivity, despite similar patterns of heart rate (an objective measure of effort). This suggests that anxiety sensitivity can amplify perceived exertion momentarily during physical activity and may possibly have an impact over prolonged physical activity.

Since individuals with elevated anxiety sensitivity have a more challenging experience with physical activity (e.g., increased fear, lower enjoyment), it makes sense that their ability to tolerate the experience differs. In a study of treatment-seeking individuals with a variety of cardiovascular or pulmonary medical conditions, participants completed a six-minute walk test as a measure of exercise tolerance. This test involved having participants walk as quickly as they could for six minutes, and the distance they walked was measured. The researchers examined the predictive value of anxiety sensitivity subscale scores in predicting exercise tolerance above and beyond gender, age, and their rehabilitation status. Results indicated that adding anxiety sensitivity subscale scores explained an additional 15% of the variance in exercise tolerance. As well, anxiety sensitivity physical (but not cognitive or social) concerns was a significant predictor of lower exercise tolerance (Kraemer et al., 2021). Similarly, Farris and colleagues (2016) found that individuals with higher anxiety sensitivity performed more poorly on a graded maximal treadmill exercise task where speed and incline increased over time and participants were encouraged to continue for as long as they were able. The researchers also found a significant interaction effect of anxiety sensitivity and exercise self-efficacy (i.e., a belief in one's ability to complete exercise regardless of circumstance) in predicting task performance. At

high levels of exercise self-efficacy, anxiety sensitivity was unrelated to task performance; at low levels of exercise self-efficacy, anxiety sensitivity was associated with poorer task performance. Thus, it appears as though the role of anxiety sensitivity on exercise participation is complex and involves the interaction of several other factors.

Anxiety sensitivity can also impact the experience during physical activity by moderating the effect of caffeine on pain during physical activity. In one study, participants reported significantly less leg muscle pain during cycling after ingesting caffeine than after ingesting placebo. The impact of caffeine on leg muscle pain was moderated by anxiety sensitivity, however. Individuals with lower levels of anxiety sensitivity had greater reductions in leg pain when taking caffeine compared to those with higher anxiety sensitivity (Gliottoni & Motl, 2008). The researchers suggested that the negative interpretation of bodily sensations from those high in anxiety sensitivity may play a role in their results. Specifically, they suggested that individuals high in anxiety sensitivity may interpret physiological responses from caffeine differently, which may subsequently impact pain response. Aligned with this suggestion, perhaps caffeine increases arousal sensations, which individuals high in anxiety sensitivity would be attentive to, and this serves as a distraction from pain.

Taken together, these studies suggest that anxiety sensitivity may contribute to increased negative experiences prior to and during physical activity. However, most research in this area has examined the experience of individuals who engage in low levels of physical activity or general samples (who, as reviewed previously, tend to engage in low levels of physical activity). The role of anxiety sensitivity in the experience physical activity for more physically active groups (e.g., athletes) remains unknown. Nonetheless, existing research supports the notion that anxiety sensitivity is a barrier to physical activity participation. Either directly or indirectly (e.g.,

though reduced physical fitness), this barrier appears to also impact the ability to tolerate the experience of physical activity.

Intervention Studies

There is an accumulation of evidence to suggest that physical activity reduces anxiety sensitivity. Theoretically, physical activity reduces anxiety sensitivity by serving as a form of interoceptive exposure. Interoceptive exposure works by exposing individuals to their feared sensations and allowing them to learn that the feared consequence does not occur or that they can cope effectively with any negative consequences that may occur (Abramowitz et al., 2019). For example, an individual who is fearful of fainting when experiencing shortness of breath may engage in physical activity to experience shortness of breath and learn that either they do not faint or even that they can manage this experience if they do.

In one of the first studies to examine the impact of physical activity on anxiety sensitivity, Broman-Fulks et al. (2004) found that a two-week, six session exercise intervention significantly reduced anxiety sensitivity. Subsequent research has shown that even a single exercise session is sufficient to reduce anxiety sensitivity (Broman-Fulks et al., 2015; LeBoutillier & Asmnundson, 2015). Exercise can also reduce anxiety sensitivity in clinical populations. For example, a six-week intervention involving high intensity interval training was shown to significantly reduce anxiety sensitivity in individuals with asthma (O'Neil & Dogra, 2020). The impact of physical activity on anxiety sensitivity in a real-world setting was tested in a study by Olthuis and colleagues (2020). Results showed that an 8-week learn to run program significantly reduced anxiety sensitivity, and symptoms of panic, social anxiety, generalized anxiety, and depression among women high in anxiety sensitivity. Participants who completed the program also indicated (via qualitative interview) that the group led to continued

participation in physical activity, improved self-efficacy, and mastery. Participants expressed that the social component of the group was important and involved connection and support. Participants also reported that the leaders of the group and gradual nature of the physical activity exposure were important to its success.

Intervention studies suggest there may be gender differences in the effects of physical activity on anxiety sensitivity. Medina et al. (2014) compared the effect that a two-week exercise program had on anxiety sensitivity for men and women. They found that men and women had similar reductions in anxiety sensitivity relative to a waitlist group from pre-treatment to post-treatment and from pre-treatment to three-week follow up. However, there were gender differences in the extent of anxiety sensitivity change from pre-treatment to mid-treatment (i.e., one week after the start of intervention) relative to the waitlist control, with men showing greater reductions in anxiety sensitivity. These results indicated that men showed a greater initial treatment response, but that anxiety sensitivity reductions were similar between men and women following the completion of the two-week protocol.

Research has also examined the effects of various forms of physical activity (e.g., aerobic exercise, resistance training) on anxiety sensitivity. In one study (Broman-Fulks et al., 2015), a single session of aerobic exercise or resistance training significantly reduced anxiety sensitivity. However, only aerobic exercise (not resistance training) reduced reactivity to a CO_2 challenge task. Results of a randomized controlled trial (LeBouthillier & Asmundson, 2017) indicated that during a four-week intervention, individuals assigned to waitlist control and those who completed aerobic exercise did not significantly reduce their anxiety sensitivity. However, those that completed a resistance training intervention significantly reduced their anxiety sensitivity relative to baseline levels and maintained these reductions at follow-up periods. The researchers

explained that participants rated the resistance training as more enjoyable, which may have contributed to the results. However, participants in either experimental condition reported similar levels of session difficulty, session worth, effort given, and motivation. In contrast, another randomized controlled trial (Mason & Asmundson, 2018), found that two different aerobic exercise conditions (50 minutes of moderate intensity aerobic exercise or 10 minutes of sprint interval training) significantly reduced anxiety sensitivity compared to a waitlist control group. Both active interventions had a comparable effect on global anxiety sensitivity, and this was maintained at 3-day and 7-day follow-up. Interestingly, the active interventions appeared to have differing effects on anxiety sensitivity domains. The moderate intensity aerobic exercise significantly reduced anxiety sensitivity cognitive and social concerns while the sprint interval training significantly reduced anxiety sensitivity physical concerns. Implications of this study suggest that anxiety sensitivity subscale domains are important to consider when determining which type of physical activity is best suited to reduce anxiety sensitivity for a given individual.

Importantly, there is research to suggest that physical activity has a specific effect on anxiety sensitivity, rather than a broad effect on all transdiagnostic constructs. A single session of exercise (either 20 min on a treadmill or resistance training) has been shown to reduce anxiety sensitivity, but have no significant effect on distress intolerance, discomfort intolerance, or state anxiety (Broman-Fulks et al., 2015). In the randomized controlled trial that compared aerobic exercise and sprint interval training to waitlist control (Mason & Asmundson, 2018), while both active exercise interventions significantly reduced anxiety sensitivity, neither significantly impacted distress intolerance nor intolerance of uncertainty. In another randomized controlled trial where participants completed 30 minutes of aerobic exercise (experimental condition) or stretching (control condition), the intervention significantly reduced anxiety sensitivity, but did

not impact intolerance of uncertainty or distress intolerance. Intervention effects were present for global anxiety sensitivity as well as for physical, cognitive, and social concerns domains (LeBouthillier & Asmundson, 2015).

When a cognitive restructuring component (i.e., learning to challenge negative thoughts) is added to physical activity interventions for anxiety sensitivity, the interventions appear to remain effective, but the additional cognitive restructuring does not seem to add additional value. When comparing the effects of a two-week exercise intervention, a two-week exercise plus cognitive restructuring intervention, and a waitlist control, results indicated that both active groups significantly reduced anxiety sensitivity and to a similar degree (Smits, Berry, Rosenfield et al., 2008). Perhaps the interoceptive experience during exercise leads to naturally occurring cognitive change and as a result, structured cognitive interventions are not of additional value. Deacon et al. (2012) also found that the addition of cognitive reappraisal or diaphragmic breathing did not lead to further reductions in anxiety sensitivity compared to interoceptive exposure (in the form of straw breathing) alone. They suggested that the interoceptive exposure for anxiety sensitivity may be sufficient to change cognitions because it can provide clear evidence immediately following the exposure to disprove the feared belief. For example, an individual fearful that an increased heart rate will lead to a heart attack can more easily disprove this belief following exposure than an individual who believes they will develop a disease following contamination.

Overall, there is clear evidence that exercise can reduce anxiety sensitivity. Meta-analytic results representing 289 participants from six randomized controlled trials indicated that exercise has a medium to large significant effect on reducing anxiety sensitivity (Jacquart et al., 2019). This effect was larger than was shown for other transdiagnostic constructs, namely, distress

tolerance, stress reactivity, and general self-efficacy. There was a significant amount of heterogeneity in the results of exercise reducing anxiety sensitivity, suggesting that moderators are involved in this effect.

Summary

As shown in the literature reviewed above, physical activity is one of the most important health behaviours when it comes to the prevention of physical and mental health dysfunction. Yet, around the world, the low rates of individuals who meet minimum guidelines for physical activity is concerning. Anxiety sensitivity is an important health-relevant factor that may play a role in physical activity avoidance. Individuals with high levels of anxiety sensitivity may avoid physical activity because it brings on many of the anxiety-related sensations they fear (e.g., shortness of breath). Overall, research appears to suggest an inverse relationship between anxiety sensitivity and physical activity, although there are mixed results and some moderators potentially involved. Research suggests that anxiety sensitivity is associated with different experiences during physical activity such as increased fear and reduced enjoyment. Fortunately, anxiety sensitivity is malleable. Physical activity in a variety of forms (e.g., aerobic running, high intensity interval training) and lengths (e.g., two-week programs or single session programs) has been shown to significantly reduce anxiety sensitivity and associated mental health concerns. However, a question remains how athletes, with elevated physical activity and reduced anxiety sensitivity (DeWolfe et al., 2022), have similar levels of mental health concerns (e.g., Gorczynski et al., 2017; Rice et al., 2019). Further understanding of the anxiety sensitivity–physical activity relationship and its consequences has important implications for increasing physical activity levels and improving health.

Dissertation Aims

The overarching aim of this dissertation was to provide novel insight into the relationship between anxiety sensitivity and physical activity. Research into this relationship can provide value by promoting insights on how to increase physical activity behaviour, reduce anxiety sensitivity, or both. The review of the literature above highlights a few key gaps in our understanding of the anxiety sensitivity–physical activity relationship that warrant further investigation. These gaps are addressed in the three studies that make up this dissertation. By bridging these gaps, it is hoped that the insights gained can be used to promote physical activity and improve health outcomes in the population.

Study 1: Anxiety Sensitivity and Physical Activity are Inversely Related: A Meta-Analytic Review

Although it is common for studies to cite an inverse relationship between anxiety sensitivity and physical activity, the narrative review of the literature above highlighted mixed results regarding this relationship. Previous literature also revealed that this relationship may be moderated by other factors (e.g., physical activity intensity, impulsivity; Galbraith et al., 2022). As well, most research relies on a single measure of anxiety sensitivity and/or physical activity and there is a need to assess the strength of this relationship across measurement instruments. Thus, an initial step for this dissertation was to clarify the presence, strength, and direction of the relationship between anxiety sensitivity and physical activity. Thus, Study 1 aimed to provide the best available estimate of the true strength of the anxiety sensitivity–physical activity relationship and explore potential moderators by conducting a meta-analysis. Based on the literature reviewed above (e.g., Gomez et al., 2021; Hearon et al., 2014; McWilliams & Asmundson, 2001; Moshier et al., 2013), it was hypothesized that anxiety sensitivity and physical activity would have a significant inverse relationship. It was also hypothesized that the

strength of this relationship would increase with increasing physical activity intensity, increasing body mass index, and male sex. Additional moderators assessed were treated as exploratory.

Study 2: Gender Differences in Physical Activity are Partially Explained by Anxiety Sensitivity in Post-Secondary Students

In the literature review, it became clear that there exist various group differences in physical activity levels. One of these differences is that women tend to engage in lower amounts of physical activity than men. This stood out as concerning and requiring further attention. The literature review also suggested that women tend to have higher levels of anxiety sensitivity than men and that anxiety sensitivity and physical activity appear to be inversely related. Taken together, these results indicate that anxiety sensitivity may be a contributor to the gender differences in physical activity levels. Thus, the purpose of Study 2 was to test the mediational role of anxiety sensitivity in explaining the effect of gender on physical activity levels. It was predicted that anxiety sensitivity would at least in part mediate or explain gender differences in physical activity levels.

Study 3: Transdiagnostic Mental Health and Athletes: Initial Support for Anxiety Sensitivity

One important characteristic of anxiety sensitivity is its role as a transdiagnostic risk factor. As explained in the literature review above, anxiety sensitivity is associated with a variety of mental health concerns in general population and clinical samples, particularly emotional disorder symptoms. Study 3 aimed to add to the understanding of the transdiagnostic properties of anxiety sensitivity as it relates to physical activity but in a population not previously tested in this regard. As highlighted in the literature review, previous research has shown that anxiety sensitivity is involved in physical activity–mental health relationships in clinical populations.

Previous research has also shown that physical activity reduces anxiety sensitivity and, independently, that reductions in anxiety sensitivity have led to decreases in mental health symptoms. Thus, it remains an open question as to whether anxiety sensitivity functions as a transdiagnostic risk factor for mental health problems in a highly physically active sample.

Study 3 examined whether anxiety sensitivity serves the same function as a transdiagnostic risk factor for various emotional disorder symptoms in a highly active sample of athletes. Athletes' experience with anxiety sensitivity and mental health may be impacted by numerous factors. These includes sport-specific factors that impact mental health (e.g., sport-related concussion; Rice et al., 2018), physiological differences that may impact arousal (e.g., higher VO_2 max, lower resting heart rate, and greater heart rate variability; Mendes et al., 2019; Pakkala et al., 2005), and their more frequent exposure to physical activity which may serve as interoceptive exposure (Stewart & Watt, 2008). Based on previous research including clinical and non-clinical samples as well as student samples (e.g., Allan et al., 2015; Naragon-Gainey, 2010; Olatunji & Wolitzky-Taylor, 2009; Scher & Stein, 2003), it was predicted that anxiety sensitivity would be positively associated with a variety of mental health symptoms assessed (i.e., generalized anxiety, social anxiety, depression, panic attacks) in the athlete sample and that this association would remain after controlling for the related yet higher-order factor of neuroticism (Cox et al., 1999). Finally, it was predicted that anxiety sensitivity subscales would predict unique variance in emotional disorder symptoms above and beyond the other subscales. Specifically, it was hypothesized that anxiety sensitivity social concerns would uniquely predict social anxiety disorder symptoms, anxiety sensitivity cognitive concerns would uniquely predict symptoms of depression, generalized anxiety and panic, and that anxiety sensitivity physical

concerns would uniquely predict past-year panic attacks (Olthuis, Watt, & Stewart, 2014; Allan, Capron, et al., 2014).

CHAPTER 2. STUDY 1: ANXIETY SENSITIVITY AND PHYSICAL ACTIVITY ARE INVERSELY RELATED: A META-ANALYTIC REVIEW

Study 1 is based on a manuscript published by Elsevier in the journal Mental Health and Physical Activity on August 9th, 2023, available online: https://www.sciencedirect.com/science/article/abs/pii/S1755296623000467 or https://doi.org/10.1016/j.mhpa.2023.100548

The manuscript prepared for this study is presented below. Readers are advised that Christopher DeWolfe, under the supervision of Dr. Sherry Stewart and Dr. Margo Watt, was responsible for study design, pre-registration, study screening and data extraction (along with a second screener), interpretation of findings and writing of the manuscript. Christopher was a collaborator in the data-analysis of this manuscript. Christopher incorporated feedback from co-authors and led revisions required for publication. The current reference for this paper is:

DeWolfe, C. E. J., Galbraith, M. K., Smith, M. M., Watt, M. C., Olthuis, J. V., Sherry, S. B., & Stewart, S. H. (2023). Anxiety sensitivity and physical activity are inversely related: A meta-analytic review. *Mental Health and Physical Activity,* Article 100548. https://doi.org/10.1016/j.mhpa.2023.100548

Abstract

The relation between anxiety sensitivity and physical activity is important because of the significant physical and mental health improvements physical activity yields for individuals with elevated anxiety sensitivity. Most studies suggest anxiety sensitivity has a negative relation with physical activity; however, there are mixed results regarding the presence and magnitude of this association. This study aimed to synthesize and analyze the existing literature to clarify the presence/magnitude of this association and assess various potential moderators. A comprehensive search identified 43 eligible studies, including 10,303 participants. Results revealed a significant, albeit small magnitude, inverse relation between anxiety sensitivity and physical activity without intervention (r = -.09). The relation was stronger with increasing physical activity intensity. Mental health status moderated the relation with general samples (versus clinical mental health samples). The relation was significant for physical and cognitive concerns, but not social concerns. These results suggest elevated anxiety sensitivity is associated with lower levels of physical activity, which is a risk factor for many health concerns and, therefore, anxiety sensitivity should be targeted for interventions to increase physical activity involvement.

Keywords: anxiety sensitivity, physical activity, exercise, transdiagnostic, mental health

Introduction

Anxiety sensitivity is a fear of anxiety and anxiety-based sensations due to a belief that the consequences will be catastrophic (Reiss & McNally, 1985). For example, an individual high in anxiety sensitivity may fear that a rapid heart rate when anxious is an indicator of an impending heart attack. Anxiety sensitivity consists of three sub-dimensions: a physical concerns dimension involving fear that physical symptoms of anxiety (e.g., elevated heart rate) will lead to a feared outcome (e.g., heart attack), a cognitive concerns dimension involving fear that cognitive symptoms of anxiety (e.g., racing thoughts) will lead to a feared outcome (e.g., going crazy), and a social concerns dimension involving fear that social symptoms of anxiety (e.g., others noticing one sweating) will lead to a feared outcome (e.g., negative evaluation). Elevated anxiety sensitivity is associated with increased rates of anxiety and depression (Naragon-Gainey, 2010; Olatunji & Wolitzky-Taylor, 2009; Warren et al., 2021). Anxiety sensitivity can effectively be reduced using brief (i.e., six sessions or less) interventions (Fitzgerald et al., 2021). Moreover, interventions targeting anxiety sensitivity can reduce symptoms across anxiety disorders (Olthuis, Watt, Mackinnon, et al., 2014) and reduce symptoms of depression (Smits, Berry, Rosenfield, et al., 2008). Thus, anxiety sensitivity has important transdiagnostic implications for preventing and treating anxiety disorders.

Anxiety Sensitivity and Physical Activity

A key component of treatment for anxiety sensitivity is interoceptive exposure which involves eliciting the physiological sensations without the feared consequences. This allows an individual to learn that the sensations are less harmful than they had anticipated and that they can cope with these sensations (Abramowitz et al., 2019). One form of interoceptive exposure for anxiety sensitivity is physical activity. Physical activity gives rise to many of the sensations

feared by those with high anxiety sensitivity (e.g., dizziness) without the feared consequences (e.g., fainting). Indeed, meta-analytic results have shown that physical activity reduces anxiety sensitivity (Jacquart et al., 2019). Importantly, reductions in anxiety sensitivity following physical activity interventions are associated with reductions in associated anxiety and depression (Smits, Berry, Rosenfield, et al., 2008). Evidently, the relation between physical activity and anxiety sensitivity has crucial mental health implications.

Despite its benefits for anxiety sensitivity, physical activity gives rise to many of the sensations that individuals with elevated anxiety sensitivity fear. Thus, researchers have examined whether high anxiety sensitivity is associated with lower physical activity levels. Several studies have found a negative association between anxiety sensitivity and physical activity (e.g., DeWolfe et al., 2020; Hearon & Harrison, 2021; Sabourin et al., 2011). However, there are inconsistencies in the literature on the existence, direction, and strength of this association. For example, several studies have failed to find a significant relation between these two variables (e.g., DeBoer et al., 2012; Moshier et al., 2016), and other studies have found a positive association. As another example, Hearon and colleagues (2014) found a positive relation (r = .43) between anxiety sensitivity and physical activity in normal-weight individuals. Thus, clarity on the presence, direction, and magnitude of this relation is needed.

Indeed, the anxiety sensitivity–physical activity relation appears to have many intricacies. For example, Moshier et al. (2013) found a varied pattern of results when examining this relation across physical activity intensities, by evaluating anxiety sensitivity as a continuous as well as a categorical variable, and with and without the use of sex as a covariate. When evaluating anxiety sensitivity as a continuous variable, the researchers found a significant inverse relation between anxiety sensitivity and physical activity, but only for vigorous-intensity physical activity (not

moderate-intensity physical activity or walking) and when sex was not included as a covariate. When anxiety sensitivity was examined as a categorical variable, the significant difference between the high and low anxiety sensitivity groups in vigorous-intensity physical activity remained significant after controlling for sex when using a cut-off score of 20 (based on large sample mean values), but not 25 (based on clinical cut-off scores; Reiss et al., 2008). The Moshier et al. (2013) study highlights the need to consider moderators, a point often overlooked in the literature, when examining the anxiety sensitivity–physical activity relation. It appears that inconsistencies in the literature on the presence, direction, and strength of this relation may be attributable to a combination of sample characteristics (e.g., sex), measurement characteristics (e.g., anxiety sensitivity cut-off score used), and physical activity characteristics (e.g., physical activity intensity).

Moderators of the Anxiety Sensitivity–Physical Activity Relation

A few moderators of the anxiety sensitivity–physical activity relation have been identified, but results have not always been consistent. Several studies have found that the significance of the relation depends on the intensity of physical activity (Moshier et al., 2013; Galbraith et al., 2022), but not all have found this (Gomez et al., 2021). Body mass index has also been shown to moderate the relation: individuals high in both body mass index and anxiety sensitivity engaged in less moderate-intensity physical activity, while individuals with low body mass index and high anxiety sensitivity engaged in significantly more moderate-intensity physical activity (Hearon et al., 2014). The role of body mass index, however, has not been found in all studies (Hearon & Harrison, 2021).

Sex also appears to impact the relation between anxiety sensitivity and physical activity. McWilliams and Asmundson (2001) found a significant inverse relation for men but not women.

Gomez et al. (2021) found an interaction between sex and anxiety sensitivity in predicting walking minutes per day and total physical activity minutes per day, but not moderate-intensity or vigorous-intensity physical activity minutes per day. For walking minutes per day, anxiety sensitivity and physical activity had a significant inverse relation for men but a significant positive relation for women. For total physical activity minutes per day, anxiety sensitivity was associated with lower levels of physical activity in men but did not impact physical activity levels for women.

There are other plausible moderators of the anxiety sensitivity–physical activity relation that may warrant consideration. For example, individuals who smoke have reduced cardiorespiratory fitness and respiratory function (Cheng et al., 2003). Thus, these individuals may experience increased tightness in their chest or breathlessness during exercise, leading to increased physical activity avoidance for smokers with high anxiety sensitivity. Similarly, older individuals have poorer cardiovascular functioning and are at increased risk for cardiovascular disease (Rodgers et al., 2019). This increased risk may lead older individuals with high anxiety sensitivity to avoid physical activity due to the increased probability that arousal sensations involve negative health implications. Finally, anxiety sensitivity is associated with various mental health conditions (Naragon-Gainey, 2010; Olatunji & Wolitzky-Taylor, 2009; Warren et al., 2021) and mental health conditions are generally associated with lower levels of physical activity (Mangerud et al., 2014). As a result, the presence of a mental health condition may compound to make physical activity more difficult for those with high anxiety sensitivity. In short, physical activity characteristics (e.g., intensity, type of physical activity), body mass index, sex, physical health conditions, smoking, age, and mental health status may interact with anxiety sensitivity to predict physical activity. The measurement used may also impact the anxiety

sensitivity–physical activity relation. Considering moderators may provide insight into the mixed findings on the anxiety sensitivity–physical activity relation in the existing literature. Taken together, there remains uncertainty as to the effects of certain moderators, while other moderators have limited support, and some have yet to be explored. Thus, a meta-analysis is needed to determine which moderators are supported across the literature, to explore additional moderators, and to identify gaps requiring further study.

Objectives and Hypotheses

Given the existing body of research on the anxiety sensitivity–physical activity relation, the mixed findings these studies have yielded, and the potential for the role of important moderators in this association, a synthesis of existing findings is needed. Thus, the primary aim of this study was to meta-analyze existing research and determine the strength of this relation in populations who have not received intervention. A secondary aim was to assess the potential moderating roles of sample characteristics (i.e., sex, age, race, mental health status, body mass index, smoker status, physical condition, anxiety sensitivity level), the measure used (i.e., anxiety sensitivity and physical activity measures), physical activity characteristics (i.e., type, intensity), and study characteristics (i.e., publication status, year of publication, location of study, study quality). To date, studies examining the anxiety sensitivity–physical activity relation have used a variety of relevant measures for both anxiety sensitivity and physical activity with various populations (e.g., community and clinical samples, various age and racial compositions of the sample). A synthesis of the literature is needed to determine if differences in measurement and/or population are contributing to the mixed results on the strength of the anxiety sensitivity–physical activity relation.

Based on the existing literature (e.g., DeWolfe et al., 2020; Gomez et al., 2021; Hearon & Harrison, 2021; Sabourin et al., 2011), we expected to find a significant inverse relation between anxiety sensitivity and physical activity. We also expected body mass index, physical activity intensity, and sex to moderate this relation. Specifically, we predicted that with higher body mass index, greater physical activity intensity, and male sex, the inverse anxiety sensitivity–physical activity relation would increase in magnitude. All other moderators were treated as exploratory.

Method

The protocol for this meta-analysis was registered on PROSPERO (*CRD4202230783*) and can be accessed at https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=307831.

Selection of Studies

The following nine databases were selected for the search: Academic Search Premier, CINAHL, EmBASE, ProQuest Dissertations, PubMed – Medline, PsycINFO, Scopus, Sport Discuss, and Web of Science. The following keywords and Boolean search terms were used to retrieve potential studies from the databases: ("Anxiety Sensitiv*" OR "fear of fear" OR "sensitivity to anxiety") AND (exercise OR "physical activit*" OR "physically active" OR inactiv* OR pedometer OR "steps per day" OR "steps per week" OR running OR walking OR swimming OR biking OR cycling OR calisthenic* OR "weight training" OR "resistance training" OR "strength training" OR Actigraph* OR accelerometer OR "activity level" OR aerobic OR anaerobic OR "leisure time" OR sport OR athlet* OR sedentary OR sitting). Studies were included if they used a validated measure of anxiety sensitivity (i.e., a measure with evidence of appropriate psychometric properties demonstrated in more than one study) and any measure of physical activity (prior to intervention in the case of intervention studies). Physical

activity was operationally defined as a frequency (e.g., number of steps per day), duration (e.g., minutes spent exercising), or behavioural indicator of performance of body movement (e.g., distance traveled in 6 minutes), or a combination of these (e.g., metabolic equivalents). Behavioural indicators of performance may appear to be different than the other indices of physical activity. They were included as individuals with elevated anxiety sensitivity may reduce their behavioural performance (e.g., go slower during running) to avoid increased feared arousal sensations. As well, studies that assessed an opinion of exercise (e.g., "I consider myself a regular exerciser") were excluded. Additionally, studies that screened in participants on both anxiety sensitivity and physical activity were excluded as this would impact the range of scores (i.e., restricted range). Only English language studies were included. The search was last updated on November 23, 2022. Upon completion of the search, results were uploaded into Covidence systematic review software (Veritas Health Innovation, 2022) to complete the screening procedure.

Study Screening

The PRISMA diagram (Page et al., 2021) outlining the study screening process is shown in Figure 2.1. The search revealed 1303 studies. Two studies were added that were known by the research term as eligible but not captured in the search. This led to 1305 studies for abstract screening. After 705 duplicates were removed, 600 studies were screened at the abstract level and 174 of these were screened at the full text level. Through the abstract screening phase, we took a liberal approach by allowing studies that included words broadly associated with physical activity (e.g., interoceptive exposure) to undergo full-text screening. This was done to capture studies that used physical activity levels as a covariate or eligibility criteria rather than as a primary outcome. Following full-text screening, 59 studies were identified as eligible to be

included in the meta-analysis. During abstract and full text screening, the first and second author both assessed for eligibility independently. These authors met weekly to resolve any discrepancies. Agreement between screeners was 96% for the abstract screening and 97% for the full-text screening. Cohen's Kappa was .91 for abstract screening and .92 for full-text screening, both which are deemed "Almost Perfect" (McHugh, 2012). Discrepancies were resolved through discussion to consensus.

Data Extraction

Emails requesting required data or analyses were sent to corresponding authors for studies that met inclusion criteria but did not report the required results. If authors did not respond to the email request, they were sent two follow-up emails. Studies meeting eligibility criteria that were not included in the analyses due to our failure to secure the required data from authors are shown in supplementary materials. This process resulted in 43 studies (72.9% of eligible studies) and 10,303 participants included in analyses of the main effect. Often studies did not have the data available as anxiety sensitivity or physical activity were used as screening variables.

For the 43 studies where data were available, the following variables were extracted: publication status (i.e., published study, dissertation), year of publication, location of study, percent female participants, percent White participants, mean age, anxiety sensitivity measure, physical activity measure, physical activity measure type (i.e., questionnaire, objective measure), physical activity type (i.e., duration, frequency, behavioural indicator of performance, measure of energy expenditure), description of physical activity (e.g., weekly minutes of physical activity), whether low intensity physical activity was included, body mass index, mental health status of sample, physical health status of sample, and percent of sample that were smokers.

Study quality was assessed using the guide provided by Kmet, Lee, and Cook (2004). This tool was selected given it can be easily used for cross-sectional studies. Each of the first two authors rated study quality independently and the mean value was used in analysis. Characteristics of the included studies are presented in the supplemental materials.

Data Analysis

We used correlation as the overall meta-analytic effect. This effect was selected for ease of interpretation of the association between anxiety sensitivity and physical activity. Comprehensive meta-analysis software (Borenstein et al., 2005) was used to run analyses. When studies reported both a frequency (e.g., number of physical activity bouts) and duration of exercise (e.g., minutes) within a set time frame (e.g., per week), the duration was used in the main analysis as it is a more precise measure of physical activity participation. When the correlation was unavailable, available data (e.g., physical activity mean, standard deviation and *n* for high and low anxiety sensitivity groups) was converted to Pearson's *r* using the online effect size converter from Lenhard and Lenhard (2016), whenever possible. Availability of physical activity intensity data varied across studies. For studies that reported the anxiety sensitivity–physical activity relation by intensity and not overall, effects were combined to create a total effect and capture all studies in the main analysis. Due to how this inconsistency was managed, we were unable to use intensity as a formal moderator. Nonetheless, we meta-analyzed the results at each intensity to demonstrate and descriptively compare the magnitude of this effect at each level of intensity.

Random effects models were used to assess the weighted bivariate effects. Random effects models were selected due to the variability in study designs and physical activity measurement and type across studies. Hunter and Schmidt's (1990) guidelines for calculating

weighted mean effect sizes were used. Publication bias was assessed using a visual inspection of funnel plots and Egger's test. In cases where publication bias was deemed present, "trim and fill" estimates were used for comparison.

Q_T and I^2 were used to assess the heterogeneity of weighted mean effects and total variation across studies due to heterogeneity, respectively. If there was sufficient heterogeneity as indicated by Q_T, moderators of the overall anxiety sensitivity–physical activity relation were assessed. We completed meta-regression to assess the impact of each moderator first individually and then (when possible) in combination. Consistent with previous meta-analyses (e.g., Muyingo et al., 2020), we examined the main moderation results while keeping *k* consistent. Although this reduces *k* to the number of studies that reports all variables, this ensures that any differences when examining moderators independently versus simultaneously are not due to different data being included. To avoid significantly reducing *k*, variables were only included in the main meta-regression analyses if almost all available studies reported the required data. This resulted in 12 moderators assessed in the main analyses and four assessed separately. Given 16 moderators were assessed in the main moderation analysis, a Bonferroni correction was applied to our *p-value*, resulting in an adjusted *p-value* of .003 (i.e., .05/16). Additionally, we explored if anxiety sensitivity cut-off values moderated the anxiety sensitivity–physical activity relation. We classified studies based on whether their average score was above or below previously identified cut-off scores for the Anxiety Sensitivity Index (ASI; Peterson & Reiss, 1992; cut-off = 25; Moshier et al., 2013; Reiss et al., 2008) and Anxiety Sensitivity Index – 3 (ASI–3; Taylor et al., 2007; cut-off = 23; Allan, Raines et al., 2014). We only included studies that used the ASI and ASI–3 due to insufficient studies using other measures. This analysis was separate from the main moderation analyses because of the redundancy with mental health status. As well, anxiety

sensitivity cut-off scores as a moderator assesses the magnitude of the correlation at a particular level of one of the variables, rather than examining the effect of an external variable and thus, can lead to restricted range concerns.

Results

Overall, results revealed a small significant negative direction relation between anxiety sensitivity and physical activity (r = -.09). See Table 2.1 for meta-analytic results. When examining this relation across specific anxiety sensitivity domains, a significant inverse relation was shown for physical concerns (r = -.09) and cognitive concerns (r = -.09), both of which were small in magnitude. The relation between social concerns and physical activity was not significant (r = -.05). Mean anxiety sensitivity values across studies using the ASI and ASI-3 were 21.00 and 19.40, respectively. These scores appear to lie midway between non-clinical and clinical sample norms (McHugh, 2018), which is to be expected given the mix of clinical and non-clinical samples.

When examining the magnitude of the anxiety sensitivity–physical activity relation by physical activity intensity, results revealed that the magnitude of the relation increased with increasing physical activity intensity. The anxiety sensitivity–physical activity relation was non-significant for low-intensity physical activity (r = -.03). A significant inverse relation was present for moderate-intensity physical activity (r = -.04) and vigorous-intensity physical activity (r = -.10). This pattern of results suggests a dose-response relation.

All values for Egger's test were non-significant, suggesting a lack of publication bias. This is consistent with a visual inspection of all funnel plots, which appeared symmetrical (provided in supplemental materials). Additionally, trim and fill estimates consistently provided similar point estimates to the original effects when imputing missing studies, where applicable.

Given sufficient heterogeneity, as indicated by Q_T, for the relation between anxiety sensitivity and physical activity total, moderation analyses were conducted. Moderation results are presented in Table 2.2. A two-way mixed effects model on the absolute agreement displayed moderate reliability for study quality ratings between raters (ICC = .67). Some caution should be noted as the 95% confidence interval ranged from poor to good (Koo & Li, 2016), 95% CI [.37, .81]. Average study quality score was .91 (0 = lowest possible score; 1 = highest possible score). Results of individual moderation tests revealed that only mental health status of the sample was a significant moderator (p = .002). Specifically, the inverse relation was stronger for non-clinical samples. This significant moderation effect was eliminated, however, when examined with the other moderators simultaneously (k = 34 studies). Moderators assessed separately from the other analyses included: percent of the sample that was White, body mass index, percent smokers, and anxiety sensitivity cut-off score (after controlling for anxiety sensitivity measure). The results revealed that none of these moderators were significant (percent White: k = 34, β < .001, SE = .002, p = .609; body mass index: k = 22, β = .003, SE = .009, p = .777; percent smokers: k = 12, β < .001, SE = .001, p = .505; anxiety sensitivity cut-off: (k = 38, β = .078, SE = .036, p = .033).

Discussion

As hypothesized, the meta-analytic results indicate a significant and inverse relation between anxiety sensitivity and physical activity across the captured literature. In other words, individuals with higher levels of anxiety sensitivity tend to engage in lower levels of physical activity whereas those with lower levels of anxiety sensitivity tend to engage in higher levels of physical activity. An individual who is fearful of anxiety-related body sensations (e.g., increased heart rate) would plausibly be less inclined to engage in physical activity which elicits many of these same feared sensations. The fact that physical activity can reduce anxiety sensitivity

(Jacquart et al., 2019) may also contribute to this inverse relation. The results of the present meta-analysis demonstrate this association is consistent regardless of what measurement tool is used for anxiety sensitivity or physical activity and regardless of what type of physical activity (i.e., frequency of physical activity, duration of physical activity, behavioural indicator of physical activity performance) is assessed. These findings provide the best available estimate of the true direction and magnitude of this relation.

The small magnitude of this effect may reflect the anxiety-specific nature of anxiety sensitivity. Anxiety sensitivity is a fear of anxiety-based sensations and although some of these sensations occur during physical activity, they are not one and the same. Research shows that domain-specific versions of anxiety sensitivity are better predictors of behaviour (Byers et al., 2022). Recently, a measure of exercise sensitivity has been developed (Farris et al., 2020). In a sample with cardiovascular risk factors, exercise sensitivity was a significant inverse predictor of any past week exercise. Regarding subscale scores, cardiopulmonary subscale scores (which align with anxiety sensitivity and physical concerns in particular) were a significant inverse predictor of any past week physical activity, but pain/weakness subscale scores were not.

The relation between anxiety sensitivity and physical activity in the present study revealed varied results depending on anxiety sensitivity domain (subscale). There was a significant inverse relation between physical activity and both anxiety sensitivity physical concerns and cognitive concerns. The relation between physical activity and social concerns was not significant, however. The physical sensations (e.g., shortness of breath) and potential cognitive sensations (e.g., spacing out) that are associated with anxiety and feared by individuals with elevated anxiety sensitivity can occur any time an individual engages in physical activity. As a result, physical activity may be avoided to reduce the risk of experiencing these feared

sensations. Social concerns (e.g., fear of sweating in front of others), however, can be avoided without requiring complete avoidance of physical activity by exercising alone. Thus, individuals with elevated anxiety sensitivity social concerns may be more avoidant of physical activity in the presence of others, rather than avoidant of physical activity altogether.

The significance of the anxiety sensitivity–physical activity relation also depended on the intensity of physical activity, suggesting a dose-response relationship. Specifically, the strength of the relation increased as the physical activity intensity increased (low-intensity r = -.03; moderate-intensity r = -.04; vigorous-intensity r = -.10). This is consistent with previous claims that physical activity intensity is implicated in this relation (Galbraith et al., 2022; Moshier et al., 2013). Indeed, more intense physical activity elicits a greater intensity of the physiological arousal sensations (e.g., rapid heart rate) that are feared by individuals with elevated anxiety sensitivity. Interestingly, there were no significant differences in effect size when comparing studies that included low-intensity physical activity (e.g., walking) in their overall measurement of physical activity to those that did not. This was examined as a potential moderator given low-intensity physical activity may not elicit physiological sensations strong enough to generate fear and subsequently impact physical activity levels among higher anxiety sensitive individuals. This null finding may indicate that even "low-intensity" exercises, such as walking, may give rise to feared sensations for certain individuals (e.g., those who do not typically exercise).

Mental health status of the sample was the only significant moderator of the anxiety sensitivity–physical activity relation among the moderators assessed. General population samples tended to have a stronger inverse relation between anxiety sensitivity and physical activity than samples of individuals with clinical mental health concerns. One potential explanation for this is that anxiety sensitivity may have differing relations with physical activity based on clinical

presentations. For example, anxiety sensitivity has been shown to be positively associated with eating disorder symptoms (Anestis et al., 2008), although eating disorder samples can engage in elevated and problematic levels of physical activity (Melissa et al., 2020). Thus, it may be that the anxiety sensitivity–physical activity relation is negative in some clinical samples and non-existent or positive in others, ultimately reducing the overall effect. Due to a limited number of studies examining the anxiety sensitivity–physical activity relation within a specific mental health diagnosis we were unable to test differences across diagnoses. Consistent with this explanation, however, Hearon and colleagues (2014) explained that anxiety sensitivity may lead to increased physical activity in some cases due to its relationship with health anxiety (Lees et al., 2005) and the fact that health anxiety may drive an increase in health-related behaviours. Another possibility for this moderation finding is that in clinical mental health samples, anxiety sensitivity is elevated, creating a restricted range effect that makes it more difficult to capture potential associations between anxiety sensitivity and physical activity. The moderation effect of clinical mental health status of the sample should be interpreted with caution, however, as it was no longer significant when all 12 primary moderators were examined together in the meta-regression.

Unexpectedly, body mass index was not a significant moderator of the anxiety sensitivity–physical activity relation. It may be that more extreme body mass index scores are needed to impact the relationship, as the mean body mass index of studies did not capture the extreme high end. Additionally, the lack of moderation based on anxiety sensitivity cut-off scores warrant further investigation as the effect was not significant using an adjusted alpha value but was in terms of the standard alpha value of .05. The direction of this effect (i.e., stronger relationship below cut-off scores) may be due to these samples having a restricted range

of anxiety sensitivity. It is also possible that anxiety sensitivity reduces physical activity participation until anxiety sensitivity reaches a certain critical level after which no further reductions in physical activity occur (e.g., individual is no longer engaging in physical activity outside of activities of daily living).

Limitations and Future Research

The results of the present study should be interpreted within the context of the study's limitations. First, as with all meta-analyses, it is important to note that the results of the present study are dependent on the quality of the studies included in the analyses. Nonetheless, the present study took steps to evaluate the quality of the results. This included assessing study quality and publication status as moderators of the relation, both of which were non-significant. Overall study quality appeared to be high (.92/1) and most included studies were published (i.e., 88% having gone through peer review). Our meta-analysis also used weighted effect sizes which prioritized studies with larger sample sizes. As well, publication bias was assessed and either was not present, or did not meaningfully impact results when it was corrected for. Second, our meta-analysis excluded studies that selected participants based on both anxiety sensitivity and physical activity. Although this exclusion criterion was selected to remove potential bias, it is important to interpret the results accordingly as this resulted in removal of studies with samples with elevated anxiety sensitivity and lower levels of physical activity. Third, our meta-analysis examined the relation between anxiety sensitivity and physical activity, but it did not determine the temporal direction of association. Indeed, neither directionality nor causality can be inferred from this analysis of cross-sectional data. Based on the existing literature, it appears as though a) anxiety sensitivity serves as a barrier to physical activity (Moshier et al., 2016); b) physical activity causes reductions in anxiety sensitivity (Jacquart et al., 2019); and c) a third variable like female

sex might account for this relation (e.g., Moshier et al., 2013). Additional longitudinal research, controlling for important variables like sex, is needed to further examine the causality and apparent bidirectionality of this relation.

When interpreting the results across anxiety sensitivity domains and physical activity intensity, it is important to note that these were not formally assessed as moderators. Rather, they were compared in terms of relative magnitude of effect size and significance and should be interpreted accordingly. Future research needs to further examine potential moderators of the anxiety sensitivity–physical activity relation. For example, Galbraith et al. (2022) found that impulsivity moderated the relation between anxiety sensitivity and physical activity for moderate-intensity physical activity, but replication of this finding is needed. Additional potential additional moderators could include those associated with the type or context of physical activity. For example, exercising alone versus in a group or engaging in cardiovascular exercise versus strength training should be explored. This would inform whether there are specific characteristics of physical activity that are less participated in by those with elevated anxiety sensitivity, or if it is physical activity broadly. Another need is to compare the anxiety sensitivity–physical activity relation across specific mental health samples. This would inform as to whether anxiety sensitivity is a unique barrier to physical activity for specific clinical populations, or if it is a transdiagnostic barrier. Finally, although the anxiety sensitivity–physical activity relation was not significantly different between studies using self-report measures versus objectives measures of physical activity, most studies relied on self-report measures. Future research would benefit from more objective measurement of physical activity.

Finally, future research would benefit from examining the relationship between anxiety sensitivity and exercise sensitivity, particularly in terms of how they relate to physical activity.

These two constructs share many features, and both have been inversely associated with physical activity (Farris et al., 2020). Psychometric research is needed to determine the distinctness of these constructs, and their incremental utility in predicting physical activity as well as both mental and physical health outcomes.

Clinical Implications

Despite being small in magnitude, the main effect in the present study is meaningful at the population level. It has been repeatedly argued that the importance of an effect needs to consider more than if the effect size is "small", "medium" or "large" (Durlak, 2009; Funder & Ozer, 2019) and that effect size is not an indicator of clinical importance (Kalinowski & Fidler, 2010). Indeed, researchers have argued that small correlations can have meaningful health implications. For example, Rutledge and Loh (2004) highlighted an effect size of $r = .08$ between physical fitness and mortality equating to clinically meaningful results when considering that it meant 8-year mortality was twice as high for less physically fit men (Rexrode et al., 1998).

Physical inactivity is a leading risk factor for noncommunicable disease and mortality worldwide. It is estimated that between 2020 and 2030, physical inactivity will be responsible for almost 500,000,000 preventable cases of noncommunicable disease and cost $301.8 billion USD (Costa Santos et al., 2022). Anxiety sensitivity is associated with a variety of anxiety disorders (Naragon-Gainey, 2010), and in 2019 anxiety disorders were estimated to impact over 300,000,000 people worldwide (Yang et al., 2021). Clearly, anxiety sensitivity and physical activity have widespread and serious negative consequences for many. Furthermore, researchers have argued that small effects that impact many individuals and impact behaviour repeatedly can have important implications over time (Funder & Ozer, 2019). This is the case in the present study as all individuals have a level of anxiety sensitivity and all are recommended to engage in

physical activity. Not only does this relation impact most people, it impacts them repeatedly over time, as anxiety sensitivity and the decision to engage in physical activity are both present on a daily basis. Fortunately, anxiety sensitivity is malleable (Fitzgerald et al., 2021), which is important when evaluating the meaningfulness of this effect (Matz et al., 2017). Taken together, the significant negative outcomes associated with this relation, the large population it impacts, the frequency at which it is at play, and the malleability of factors in this relationship combine to make the small effect in the present study meaningful.

Beyond population impact, the present finding that individuals with elevated anxiety sensitivity participate in less physical activity, is important for clinicians to be aware of for several reasons. First, individuals who are physically inactive are at an increased risk for serious physical health conditions (Costa Santos et al., 2022). Second, physical activity can reduce anxiety sensitivity as well as associated anxiety and depressive symptoms (Smits, Berry, Rosenfield, et al., 2008). Fortunately, the benefits of physical activity for reducing anxiety sensitivity and associated mental health symptoms have been demonstrated in an accessible community-based intervention (Olthuis et al., 2020). With this in mind, practitioners seeking to improve physical and mental health in their clients by increasing their physical activity levels may wish to consider the role of anxiety sensitivity as a barrier to physical activity participation. Indeed, anxiety sensitivity is a malleable treatment target (Fitzgerald et al., 2021) and may be a worthwhile factor to address in efforts to increase physical activity levels. Cognitive behavioural therapy (CBT) may be beneficial for individuals high in anxiety sensitivity who engage in lower levels of exercise as it includes cognitive interventions (e.g., learning to reevaluate the meaning of physical sensations; de-catastrophizing) and interoceptive exposure. Learning to reduce catastrophizing and increase tolerance of arousal sensations would reduce anxiety sensitivity and

may lead to increases in physical activity levels. Although the magnitude of the anxiety sensitivity–physical activity relation in the present study was small, it may be impacted by a multitude of factors that lead to low physical activity participation generally. A stronger relation with anxiety sensitivity may have been observed had fear-based physical activity avoidance been examined rather than physical activity per se. Targeted interventions focused on individuals who avoid physical activity due to fear/avoidance may be particularly impactful.

Conclusions

The present study adds much needed clarity to the existing literature on anxiety sensitivity and physical activity. By conducting a comprehensive meta-analysis involving 43 studies and 10,303 participants, this review provides a best estimate of the true presence, direction, and magnitude of this relation. The results revealed a significant, albeit small, inverse relation between anxiety sensitivity and physical activity. Factors such as intensity of physical activity, anxiety sensitivity domain, and mental health status appear to be involved as potentially important moderators of this relation.

Table 2.1. *Meta-Analysis Results*

Variable	*k*	*N*	*r*	95% CI	*QT*	I^2 (%)	Egger's intercept	95% CI	k^{TF}	"Trim and fill" estimates *r* [95% CI]
Anxiety Sensitivity Total	43	10,303	-.09***	[-.12, -.06]	71.90**	41.59	-.20	[-.91, .50]	0	-.09 [-.12, .06]
Anxiety Sensitivity Categories										
Physical Concerns	17	4,296	-.09**	[-.15, -.03]	41.06**	61.03	-.44	[-1.86, .98]	2	-.08 [-.14, -.01]
Cognitive Concerns	16	4,125	-.09**	[-.16, -.03]	40.60***	63.05	-.64	[-2.10, .82]	0	-.09 [-.16, -.03]
Social Concerns	16	4,124	-.05	[-.11, .01]	33.78**	55.6	-.26	[-1.63, 1.11]	2	-.04 [-.10, .02]
Physical Activity Categories										
Low Intensity	11	2,252	-.03	[-07, .01]	5.13	0.00	-.18	[-1.14, .79]	1	-.03 [-.07, .01]
Moderate Intensity	16	2,835	-.04*	[-.08, .00]	15.89	5.58	-.06	[-1.22, 1.09]	1	-.04 [-.08, .00]
Vigorous Intensity	18	3,245	-.10**	[-.16, -.05]	36.30**	53.16	-.97	[-2.41, .48]	3	-.08 [-.14, -.02]

Note. *k* = number of studies; *N* = total number of participants in *k* studies; *r* = weighted mean bivariate correlation; CI = confidence interval; *QT* = total heterogeneity; I^2 = percentage of heterogeneity; k^{TF} = number of imputed studies as part of "trim and fill" method.
*$p < .05$; **$p < .01$; ***$p < .001$.

Table 2.2. *Meta-Regression Moderation Results in Predicting the Anxiety Sensitivity–Physical Activity Relation*

Moderator (k = 34)	Point estimate (β)	Standard error	95% *CI*	*Z*	*p*-value	R^2_{analog}
Individual Moderators						
(Model 1)						.05
Intercept	.083	.113	[-.138, .303]	.73	.464	
Publication status[a]	-.178	.114	[-.401, .046]	-.156	.119	
(Model 2)						.33
Intercept	-14.076	6.758	[-27.321, -.832]	-2.08	.037	
Year of publication	.007	.003	[<.001, .014]	2.07	.039	
(Model 3)						.02
Intercept	-.133	.065	[-.260, -.006]	-2.06	.040	
% Female	.001	.001	[-.001, .003]	.67	.503	
(Model 4)						.00
Intercept	-.118	.043	[-.203, -.033]	-2.72	.006	
Mean age	.001	.001	[-.001, .003]	.67	.502	
(Model 5)						.25
Intercept	-.020	.099	[-.213, .171]	-.20	.840	
Physical activity type[b]						
Energy expenditure	-.036	.104	[-.239, .168]	-.34	.732	
Frequency	-.081	.103	[-.283, .121]	-.78	.433	
Duration	-.087	.101	[-.285, .111]	-.86	.389	
(Model 6)						.02
Intercept	-.094	.024	[-.142, -.047]	-3.87	<.001	
Includes low intensity physical activity[c]	.006	.034	[-.059, .072]	.18	.856	
(Model 7)						<.001
Intercept	-.118	.073	[-.261, .025]	-1.62	.105	
Physical activity measure type[d]	.028	.075	[-.118, .175]	.38	.706	
(Model 8)						<.001

Intercept	-.093	.021	[-.135, -.052]	-4.40	<.001	
Anxiety Sensitivity Measure[e]	.006	.035	[-.063, .075]	.17	.866	
(Model 9)						.08
Intercept	-.171	.272	[-.703, .361]	-.63	.529	
Study quality	.085	.288	[-.479, .648]	.29	.768	
(Model 10)						.26
Intercept	-.100	.034	[-.166, -.034]	-2.96	.003	
Location[f]						
Europe	.057	.056	[-.054, .167]	1.00	.315	
United States	.003	.039	[-.073, .079]	.07	.942	
(Model 11)						.76
Intercept	-.109	.015	[-.138, -.081]	-7.48	<.001	
*Clinical mental health sample[g]	.111	.035	[.042, .181]	3.15	.002	
(Model 12)						.03
Intercept	-.099	.019	[-.135, -.062]	-5.30	<.001	
Physical condition sample[g]	.039	.042	[-.044, .121]	.91	.362	
Combined Moderators						
(Model 13)						1.00
Intercept	-18.413	8.18	[-34.454, -2.372]	-2.25	.025	
Publication status[a]	-.166	.141	[-.442, .111]	1.18	.240	
Year of publication	.009	.004	[.001, .017]	2.22	.027	
% Female	<.001	.001	[-003, .003]	.05	.962	
Mean age	-.002	.002	[-.005, .002]	-.97	.331	
Physical activity type[b]						
Energy expenditure	-.242	.145	[-.526, .043]	-1.67	.096	
Frequency	-.316	.150	[-.609, -.023]	-2.11	.035	
Duration	-.248	.143	[-.528, .033]	-1.73	.084	
Includes low intensity physical activity[c]	-.008	.047	[-.099, .083]	-.17	.863	
Physical activity measure type[d]	.168	.108	[-.043, .379]	1.56	.119	

Anxiety sensitivity measure[e]	-.012	.037	[-.085, .061]	-.32	.746
Study quality	.260	.372	[-.471, .990]	.70	.486
Location[f]					
Europe	-.054	.068	[-.186, .079]	-.79	.430
United States	.050	.053	[-.055, .154]	.93	.350
Clinical mental health sample[g]	.138	.058	[.024, .252]	2.38	.018
Physical illness sample[g]	.090	.052	[-.012, .191]	1.73	.084

*Significant $p < .003$; Reference variable: [a]Dissertation; [b]Behavioural indicator of performance; [c]No; [d]Behavioural measure; [e]Anxiety Sensitivity Index; [f]Canada; [g]General sample.

Table 2.3. *Sample Characteristics of Studies Included in the Meta-Analysis*

	Corr *N*	Mean age	Female %	White %	Mean BMI	Smoker %	Clinical MH	MH (%)	MH measure	Clinical PH	PH (%)	PH measure
Alcántara et al. (2020)	1417	64.70	39.10	82.10	NR	NR	No	N/A	N/A	Yes	Myocardial infarction (100)	Self-report
Bokma et al. (2022)	851	41.92	66.80	95.20	25.57	38.40	Yes	Anxiety disorders (100)	Psychiatric diagnosis	No	Various chronic diseases (45.90)	Self-report
Broderick (1996)	7	46.29	100	100	NR	0	No	N/A	N/A	Yes	Mitral valve prolapse (100)	Professional diagnosis
Broman-Fulks et al. (2018)	955	45.8	60.80	95.20	NR	NR	No	Medication for anxiety; depression (4.50; 10.90)	Self-report	No	N/A	N/A
Brown et al. (2021)	259	21.33	86.10	76.30	19.92	NR	Yes	Eating disorders (100)	Clinical interview	No	N/A	N/A
Castonguay et al. (2020)	273	54.56	57	NR	26.89	12.95	No	Anxiety disorders (30.55)	Medical interview	Yes	Various[a] (64.98)	Medical interview
Castonguay et al. (2021)	20	57.65	40.00	100	27.70	20.00	No	N/A	N/A	Yes	Non-cardiac chest pain (100)	Cardiac stress test
DeBoer et al. (2012)	167	51.02	44.90	90.20	26.36	NR	No	N/A	N/A	No	N/A	N/A
de la Flor et al. (2022)	42	36.69	76.00	NR	20.38	NR	No	N/A	N/A	Yes	Chronic tension-type headache (100)	Professional diagnosis

Table 2.3 (Continued)

	Corr *N*	Mean age	Female %	White %	Mean BMI	Smoker %	Clinical MH	MH (%)	MH measure	Clinical PH	PH (%)	PH measure
DeWolfe et al. (2020)	802	20.02	78.10	NR	NR	NR	No	N/A	N/A	No	N/A	N/A
Farris et al. (2019a)	100	37.80	100	94.00	28.10	8.00	No	Probable anxiety or depression (59.00)	PHQ-4 screener	Yes	Migraine (100)	IDMigraine screener
Farris et al. (2019b)	182	46.00	71.10	80.60	29.20	100	No	N/A	N/A	Yes	Respiratory (11.40)	Self-report
Farris et al. (2022)	19	70.90	21.10	78.90	28.60	36.80	No	N/A	N/A	Yes	Cardiovascular disease (100)	Medical assessment
Fetzner & Asmundson (2015)	33	36.90	76.00	79.00	NR	NR	Yes	Various[a] (77.42)	Self-report	No	N/A	N/A
Fitzpatrick et al. (2020)	730	17.15	53.20	NR	22.54	NR	No	N/A	N/A	No	N/A	N/A
Galbraith et al. (2022)	121	21.88	68.75	85.96	NR	NR	No	N/A	N/A	No	N/A	N/A
Gliottoni & Motl (2008)	16	23.40	100	NR	21.10	0	No	N/A	N/A	No	N/A	N/A
Gomez et al. (2021)	527	44.80	53.30	89.80	27.89	100	No	Various[b] (31.90)	PHQ-5 screener	No	Various[c] (64.90)	Self-report
Goodin et al. (2009)	79	20.10	52.00	52.00	22.60	NR	No	N/A	N/A	No	N/A	N/A

Table 2.3 (Continued)

	Corr *N*	Mean age	Female %	White %	Mean BMI	Smoker %	Clinical MH	MH (%)	MH measure	Clinical PH	PH (%)	PH measure
Hearon et al. (2014)	32	43.00	62.50	59.40	28.50	NR	No	N/A	N/A	No	N/A	N/A
Hearon & Harrison (2021)	55	19.84	67.30	67.30	26.07	NR	No	N/A	N/A	No	N/A	N/A
Herzog et al. (2022)	88	23.65	69.00	NR	21.52	NR	No	Previous MH treatment (23.00)	Self-report	No	N/A	N/A
Kraemer et al. (2021)	69	63.57	34.79	73.91	NR	0	No	N/A	N/A	Yes	Cardiovascular or pulmonary (100)	Medical assessment
LeBouthillier & Asmundson (2015)	23	34.22	69.60	87.00	NR	NR	No	MH diagnosis (13.00)	Self-report	No	N/A	N/A
LeBouthillier & Asmundson (2017) measurement A	48	31.96	77.00	89.50	28.29	NR	Yes	Anxiety-related disorder (100)	Clinical interview	No	N/A	N/A
LeBouthillier & Asmundson (2017) measurement B	48	31.96	77.00	89.50	28.29	NR	Yes	Anxiety-related disorder (100)	Clinical interview	No	N/A	N/A
Lefaivre (2009) measurement A	216	15.46	62.04	81.20	NR	NR	No	Medication or treatment for MH issues (30.99)	HHQ	No	Any limiting PA participation (2.11)	HHQ

Table 2.3 (Continued)

	Corr *N*	Mean age	Female %	White %	Mean BMI	Smoker %	Clinical MH	MH (%)	MH measure	Clinical PH	PH (%)	PH measure
Lefaivre (2009) measurement B	133	15.46	62.04	81.20	NR	NR	No	Treatment for MH past 3 months (4.49)	Self-report	No	Any limiting PA participation (11.84)	Self-report
McLeish et al. (2007)	225	23.90	45.33	94.70	NR	100	No	N/A	N/A	No	N/A	N/A
McWilliams & Asmundson (2001) sample A	188	21.20	100	86.60	NR	28.43	No	N/A	N/A	No	N/A	N/A
McWilliams & Asmundson (2001) sample B	59	21.20	0	86.80	NR	22.03	No	N/A	N/A	No	N/A	N/A
Medina et al. (2011)	114	22.31	50.88	89.50	NR	NR	No	N/A	N/A	No	N/A	N/A
Moshier et al. (2013)	233	26.00	51.10	60.10	NR	NR	No	N/A	N/A	No	N/A	N/A
Moshier et al. (2016)	145	18.80	81.00	61.00	22.51	NR	No	N/A	N/A	No	N/A	N/A
Nelson (2013)	56	35.16	60.70	50.80	NR	NR	Yes	Alcohol use/ dependence (100)	DSM-IV-TR criteria	No	N/A	N/A
Ochmann et al. (2021)	28	25.04	60.70	100	23.29	0	No	N/A	N/A	No	N/A	N/A
Olthuis et al. (2014)	74	36.30	78.80	76.30	26.56	NR	Yes	DSM diagnoses (85.00)	Clinical interview	No	N/A	N/A

Table 2.3 (Continued)

	Corr *N*	Mean age	Female %	White %	Mean BMI	Smoker %	Clinical MH	MH (%)	MH measure	Clinical PH	PH (%)	PH measure
Olthuis et al. (2020)	36	32.20	100	88.00	27.07	NR	No	N/A	N/A	No	N/A	N/A
O'Neil & Dogra (2020)	20	22.50	55.00	NR	26.00	NR	No	N/A	N/A	Yes	Asthma and EIB (100)	Self-report
Peekna (1997)	1223	NR	100	NR	NR	NR	No	N/A	N/A	No	N/A	N/A
Sabourin et al. (2011)	154	19.00	100	86.00	NR	NR	No	N/A	N/A	No	N/A	N/A
Smits & Zvolensky (2006)	39	25.86	69.20	92.30	NR	NR	Yes	Panic disorder (100)	Clinical interview	No	N/A	N/A
Smits et al. (2011)	146	20.45	47.95	94.50	NR	NR	No	Marijuana abuse; dependence (30.80; 28.80)	Clinical interview	No	N/A	N/A
Tart et al. (2010)	270	22.40	52.60	90.40	NR	50.00	No	N/A	N/A	No	N/A	N/A
Walz et al. (2016)	37	20.75	70.27	NR	NR	NR	No	N/A	N/A	No	N/A	N/A
Williamson & Dasinger (2022)	139	20.96	69.10	73.40	NR	NR	No	N/A	N/A	No	N/A	N/A

Note. Studies with multiple effects are presented individually in this table, although they were combined in the analyses. Corr *N* = number of participants used in correlation analyses; Female % = percentage females; White % = percentage White; BMI = body mass index; Smoker % = percentage smokers; MH = mental health; Clinical MH = clinical levels of mental health issues in sample; MH (%) = all reported mental health difficulties (percentage); MH measure = measurement of mental health information; PH = physical health; Clinical PH = clinical levels of physical health issues in sample; PH (%) = all reported physical health conditions (percentage); PH measure = measurement of

physical health information; PHQ-4 = Patient Health Questionnaire-4; PHQ-5 = Patient Health Questionnaire-5; HHQ = Health Habits Questionnaire; DSM-IV-TR = Diagnostic and Statistical Manual of Mental Disorders, fourth edition, text revision; EIB = Exercise-induced bronchoconstriction.

[a]Including depression, posttraumatic stress, borderline personality disorder, and anxiety disorders.

[b]Including alcohol abuse, anxiety disorders, and eating disorders.

[c]Including cardiovascular, respiratory, and neurological conditions.

Table 2.4. *Article and Measure Characteristics of Studies Included in Meta-Analysis*

	Article		Measure					
	Status	Location	AS	Mean AS (SD)	PA	Type of PA	Mean PA (SD)	Low PA
Alcántara et al. (2020)	Article	US	ASI	16.70 (15.05)	Unspecified[a,b]	Frequency	NR	No
Bokma et al. (2022)	Article	Europe	ASI	34.97 (10.02)	IPAQ[a]	Energy expenditure	NR	Yes
Broderick (1996)	Dissertation	US	ASI	19.43 (8.38)	Unspecified[c,d]	Frequency	2.12 (1.39) (times/week)	Yes
Broman-Fulks et al. (2018)	Article	US	ASI-3	11.88 (10.07)	Unspecified[c,e]	Frequency	3.48 (1.20) (times/week)	No
Brown et al. (2021)	Article	US	ASI-3	29.47 (14.86)	Item 31 of EPSI[c]	Frequency	1.16 (1.48) (Likert scale from 0-4, 0 = "Never", 4 = "Very often")	No
Castonguay et al. (2020)	Article	Canada	ASI	16.88 (11.47)	AQ[a]	Energy expenditure	NR	Yes
Castonguay et al. (2021)	Article	Canada	ASI	17.55 (7.91)	GPAQ[a]	Duration	10.75 (24.94) (mins/week)	No
DeBoer et al. (2012)	Article	US	ASI	14.47 (8.17)	IPAQ-SF[a,f]	Duration	196.11 (247.61); 194.27 (222.78) (mins/week moderate; vigorous)	No
de la Flor et al. (2022)	Article	Europe	ASI-3	17.64 (16.22)	IPAQ-SF[a]	Energy expenditure	NR	Yes
DeWolfe et al. (2020)	Article	Canada	ASI-3	19.60 (14.13)	Unspecified[c,g]	Duration	362.71 (285.01) (mins/session x days)	Yes

Table 2.4 (Continued)

	Article		Measure					
	Status	Location	AS	Mean AS (SD)	PA	Type of PA	Mean PA (SD)	Low PA
Farris et al. (2019a)	Article	US	ASI-3	23.96 (15.24)	GPAQ[a]	Duration	NR	No
Farris et al. (2019b)	Article	US	ASI-3	14.20 (13.60)	Unspecified[c,h]	Duration	36.18 (94.49) (mins/week)	No
Farris et al. (2022)	Article	US	ASI-3	18.37 (12.41)	Polar M200[i]	Duration	NR	No
Fetzner & Asmundson (2015)	Article	Canada	ASI-3	37.55 (14.75)	FLQ[a]	Frequency	NR	No
Fitzpatrick et al. (2020)	Article	Canada	SURPS	3.32 (2.38)	Indice d'activité physique[a]	Energy expenditure	3.12 (1.55) (times/week x duration/day)	Yes
Galbraith et al. (2022)	Article	Canada	ASI-3	21.47 (12.96)	IPAQ-SF[a]	Energy expenditure	2882.85 (NR) (MET mins/week)	Yes
Gliottoni & Motl (2008)	Article	US	ASI	19.00 (8.40)	Incremental exercise test[i]	Behavioural performance	248.30 (30.80) (peak power output)	No
Gomez et al. (2021)	Article	US	ASI-3	22.22 (18.03)	IPAQ-SF[a]	Duration	417.64 (674.49) (mins/week x times/week)	Yes
Goodin et al. (2009)	Article	US	ASI	18.33 (6.89)	GLTEQ[a]	Frequency	3.28 (3.07) (times/week)	No
Hearon et al. (2014)	Article	US	ASI	20.80 (11.10)	Actigraph ActiTrainer[i]	Duration	High AS = 3.38(1.77); Low AS = 2.00(1.31) (percentage of time/day)	No

Table 2.4 (Continued)

	Article		Measure					
	Status	Location	AS	Mean AS (SD)	PA	Type of PA	Mean PA (SD)	Low PA
Hearon & Harrison (2021)	Article	US	ASI-3	17.10 (13.50)	Actigraph[i]	Duration	124.20 (40.20) (mins/day)	No
Herzog et al. (2022)	Article	Europe	ASI-3	30.47 (8.82)	BSA-F[a]	Duration	589.31 (345.47) (mins/week)	No
Kraemer et al. (2021)	Article	US	ASI-3	9.45 (NR)	6MWT[i]	Behavioural performance	1365.87 (413.33) (distance in ft)	No
LeBouthillier & Asmundson (2015)	Article	Canada	ASI-3	14.70 (13.61)	HPAPQ[a]	Frequency	NR	No
LeBouthillier & Asmundson (2017) measurement A	Article	Canada	ASI-3	35.29 (15.92)	Unspecified[c,j]	Duration	35.58 (41.45) (mins/week)	No
LeBouthillier & Asmundson (2017) measurement B	Article	Canada	ASI-3	35.29 (15.92)	6MWT[i]	Behavioural performance	NR	No
Lefaivre (2009) measurement A	Dissertation	Canada	CASI	18.33 (NR)	3-DPAR[a]	Energy expenditure	5.20 (3.30) (number of 30-min blocks)	Yes
Lefaivre (2009) measurement B	Dissertation	Canada	CASI	27.60 (5.08)	Léger Beep or PACER test[i]	Behavioural performance	5.45 (2.69) (highest level on endurance test)	No
McLeish et al. (2007)	Article	US	ASI	19.39 (13.30)	EHS[a]	Duration	NR	Yes

Table 2.4 (Continued)

	Article		Measure					
	Status	Location	AS	Mean AS (SD)	PA	Type of PA	Mean PA (SD)	Low PA
McWilliams & Asmundson (2001) sample A	Article	Canada	ASI	18.07 (8.49)	Unspecified[c,k]	Frequency	2.39 (2.36) (times/week)	No
McWilliams & Asmundson (2001) sample B	Article	Canada	ASI	18.58 (8.29)	Unspecified[c,k]	Frequency	3.18 (2.36) (times/week)	No
Medina et al. (2011)	Article	US	ASI	15.89 (7.46)	EHQ-R[c]	Duration	NR	Yes
Moshier et al. (2013)	Article	US	ASI	17.50 (9.35)	IPAQ-SF[a]	Energy expenditure	3577 (2956) (MET mins/week)	Yes
Moshier et al. (2016)	Article	US	ASI	25.03 (12.21)	IPAQ[a]	Energy expenditure	1818.32 (1910.67) (MET mins/week)	Yes
Nelson (2013)	Dissertation	US	ASI	18.58 (11.23)	TLFB-E[a]	Duration	248.02 (311.18) (mins/week)	No
Ochmann et al. (2021)	Article	Europe	ASI-3	14.25 (9.57)	IPAQ[a]	Energy expenditure	NR	Yes
Olthuis et al. (2014)	Article	Canada	ASI-3	38.38 (13.59)	Unspecified[c,l]	Frequency	NR	Yes
Olthuis et al. (2020)	Article	Canada	ASI-3	35.85 (14.20)	PAM Modified Version[c]	Duration	35.00 (68.92) (mins/week)	Yes
O'Neil & Dogra (2020)	Article	Canada	ASI	17.90 (11.80)	Unspecified[c,m]	Duration	NR	No

Table 2.4 (Continued)

	Article		Measure					
	Status	Location	AS	Mean AS (SD)	PA	Type of PA	Mean PA (SD)	Low PA
Peekna (1997)	Dissertation	US	ASI	NR	Unspecified[c,n]	Frequency	NR	Yes
Sabourin et al. (2011)	Article	Canada	ASI	22.61 (NR)	PAM[c]	Duration	132.38 (NR) (times/month x mins/session)	Yes
Smits & Zvolensky (2006)	Article	US	ASI	34.97 (10.94)	EHS[c]	Frequency	NR	Yes
Smits et al. (2011)	Article	US	ASI	15.75 (8.05)	EHQ-R[c]	Duration	132.69 (175.41) (mins/week of vigorous intensity)	No
Tart et al. (2010)	Article	US	ASI	16.49 (8.52)	EHQ-R[c]	Duration	116.68 (150.64) (mins/week of moderate intensity)	Yes
Walz et al. (2016)	Article	Europe	ASI	20.67(NR)	Human OFT[i]	Behavioural performance	1078.57 (NR); 4.34 (NR) (distance in m; speed in km/h)	Yes
Williamson & Dasinger (2022)	Dissertation	US	ASI-3	NR	GPAQ[a]	Duration	NR	No

Note. Studies with multiple effects are presented individually in this table, although they were combined in the analyses. Status = publication status of study; AS = anxiety sensitivity; PA = physical activity; Low PA = study includes low intensity physical activity; Article = Peer-reviewed publication; U. S. = United States; ASI = Anxiety Sensitivity Index; ASI-3 = Anxiety Sensitivity Index-3; Frequency = times per week of physical activity; NR = not reported; IPAQ = International Physical Activity Questionnaire; Frequency = Times per week spent engaging in physical activity; Energy expenditure = Metabolic equivalent of task; EPSI = Eating Pathology Symptoms Inventory; AQ = Actimètre Questionnaire; GPAQ = Global Physical Activity Questionnaire; Duration = minutes of physical activity; IPAQ-SF = International Physical Activity Questionnaire-Short Form; FLQ = Fantastic Lifestyle Questionnaire; GLTEQ = Godin Leisure-Time Exercise Questionnaire; BSA-F = Physical Activity, Exercise, and Sport

Questionnaire; 6MWT = 6-minute walk test; HPAPQ = Healthy Physical Activity Participation Questionnaire; PAM = Physical Activity Measure; CASI = Childhood Anxiety Sensitivity Index; 3-DPAR = 3-Day Physical Activity Recall; PACER = Progressive Aerobic Cardiovascular Endurance Run; EHS = Exercise Health Survey; EHQ-R = Exercise Habits Questionnaire-Revised; TLFB-E = Timeline Followback-Exercise; OFT = open field test.

[a]Validated questionnaire.

[b]Participants asked, "In the past week, on how many days have you done a total of 30 minutes or more of physical activity?"

[c]Author-compiled questionnaire.

[d]Daily exercise log.

[e]Participants asked to rate the frequency in which they engaged in "exercise that at least moderately increases your breathing and heart rate and makes you sweat for at least 20 minutes (such as brisk walking, cycling, swimming, jogging, aerobic dance, stair climbing, rowing, basketball, racquetball, vigorous yard work, etc.)," where response options were 1) less than 1 time per week, 2) 1-2 times per week, 3) 3-4 times per week, or 4) 5+ times per week.

[f]First 4 items only.

[g]Assessed minutes of PA in the past 30 days by multiplying how many days in the past 30 participants engaged in PA and the average duration of their usual PA session.

[h]Participants asked, "How many days do you exercise at a moderate to vigorous intensity for at least ten continuous minutes;" "On the days that you exercise, how long do you exercise for?"

[i]Objective measure.

[j]Weekly minutes of PA.

[k]Weekly number of exercise sessions.

[l]Times per week of PA.

[m]Weekly minutes of moderate to vigorous PA.

[n]Number of exercise activities in the last week.

Figure 2.1. *PRISMA Flowchart*

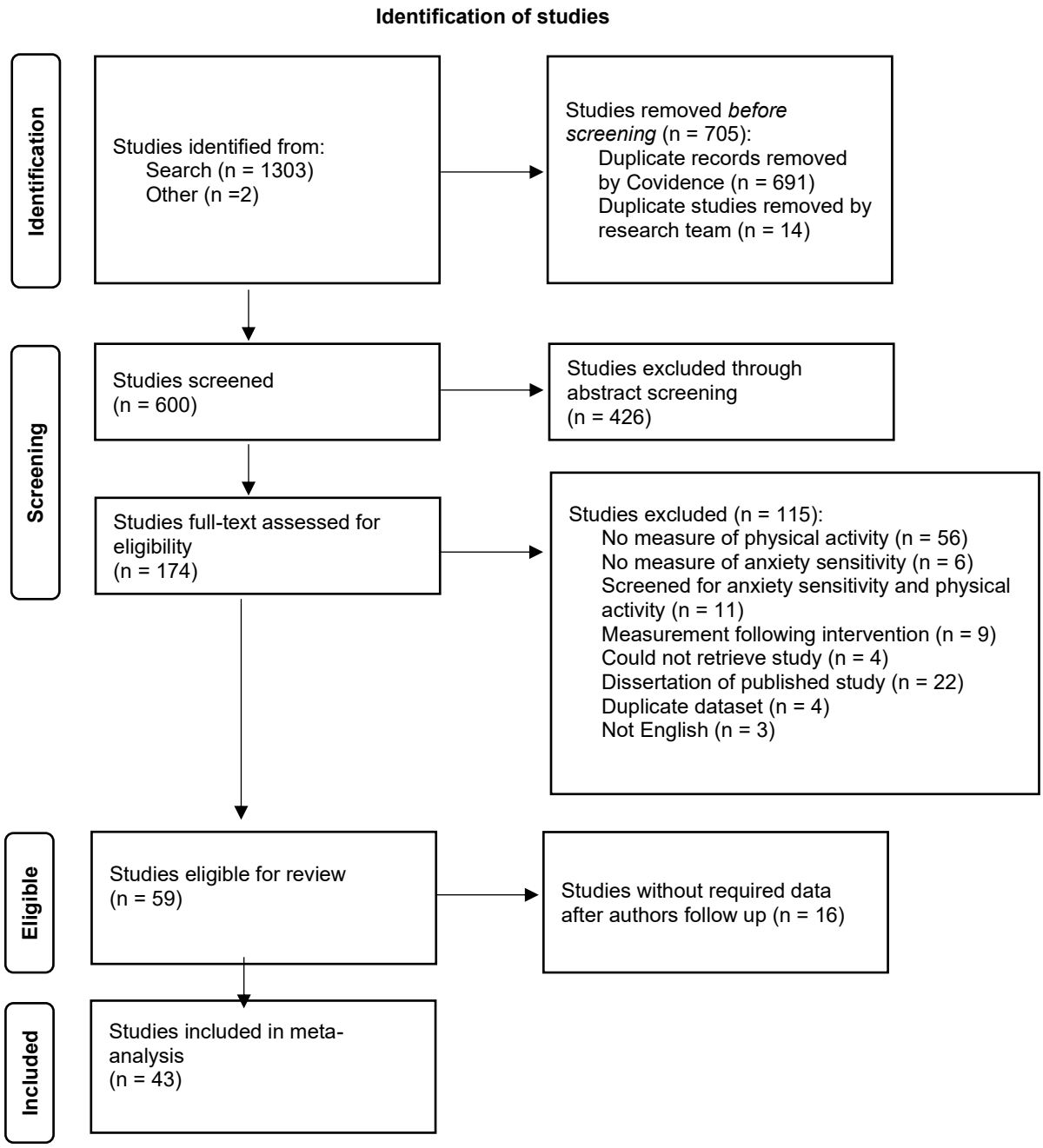


Figure adapted from Page et al. (2021).

Figure 2.2. *Significant Moderation of Clinical Mental Health Sample*

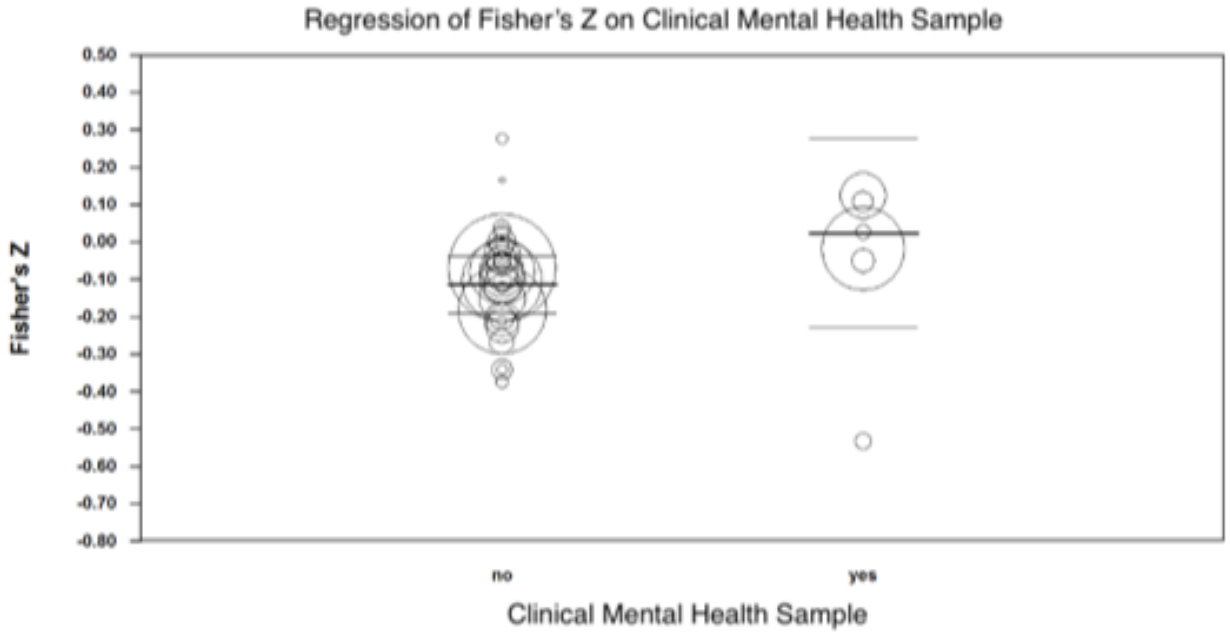


Figure 2.3. *Funnel Plot for Relation Between Physical Activity Total and Anxiety Sensitivity Total*

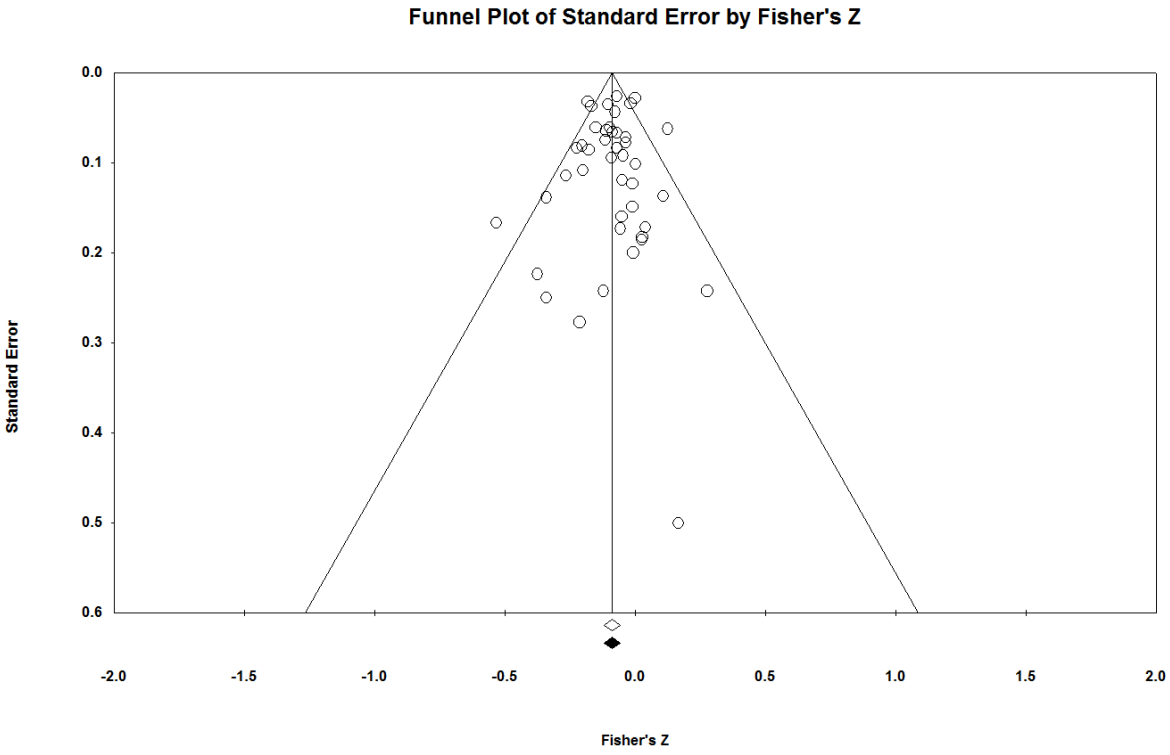


Figure 2.4. *Funnel Plot for Relation Between Low-Intensity Physical Activity and Anxiety Sensitivity Total*

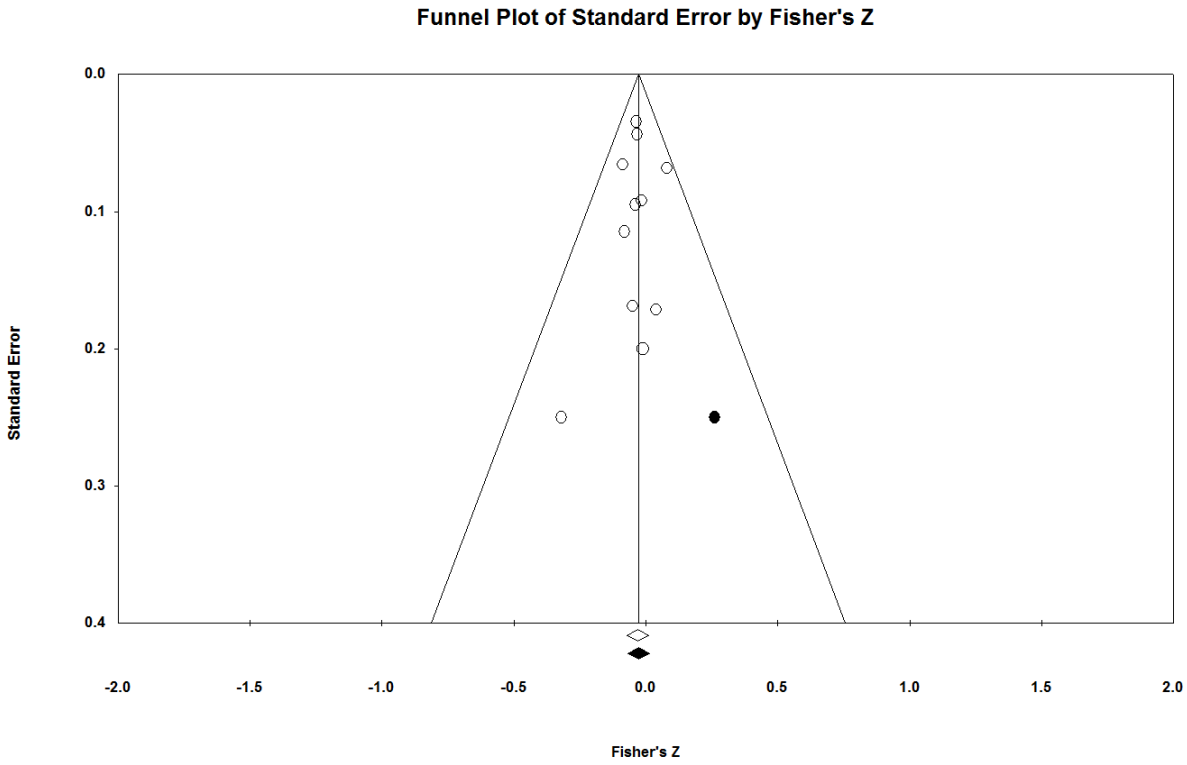


Figure 2.5. *Funnel Plot for Relation Between Moderate-Intensity Physical Activity and Anxiety Sensitivity Total*

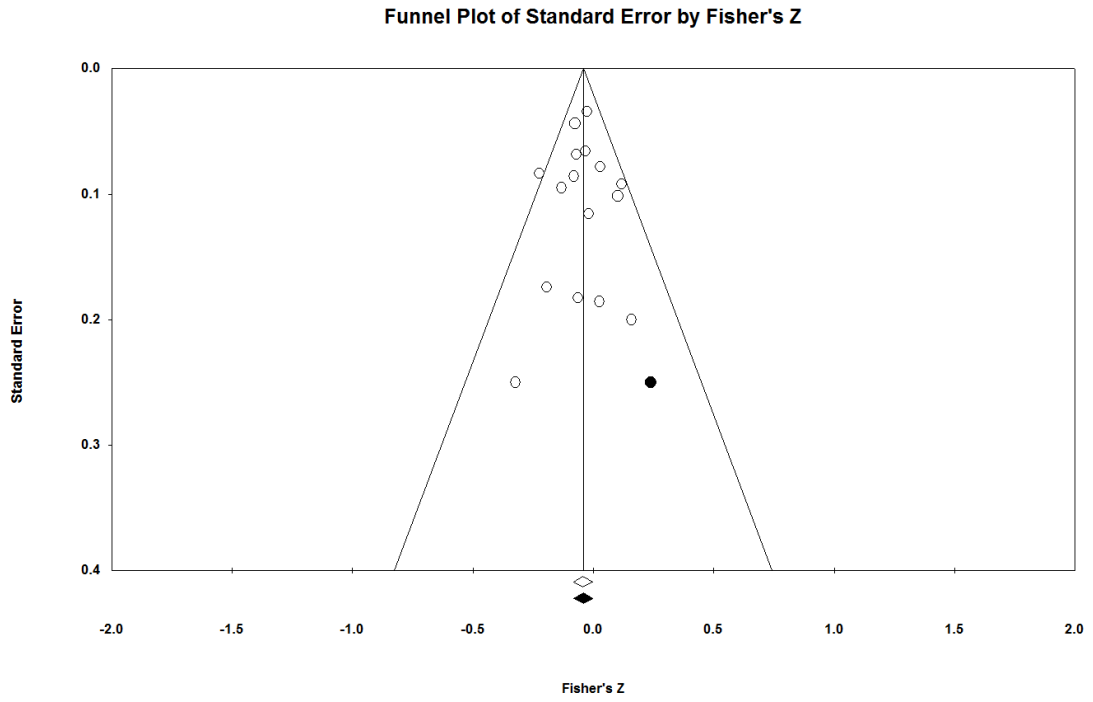


Figure 2.6. *Funnel Plot for Relation Between Vigorous-Intensity Physical Activity and Anxiety Sensitivity Total*

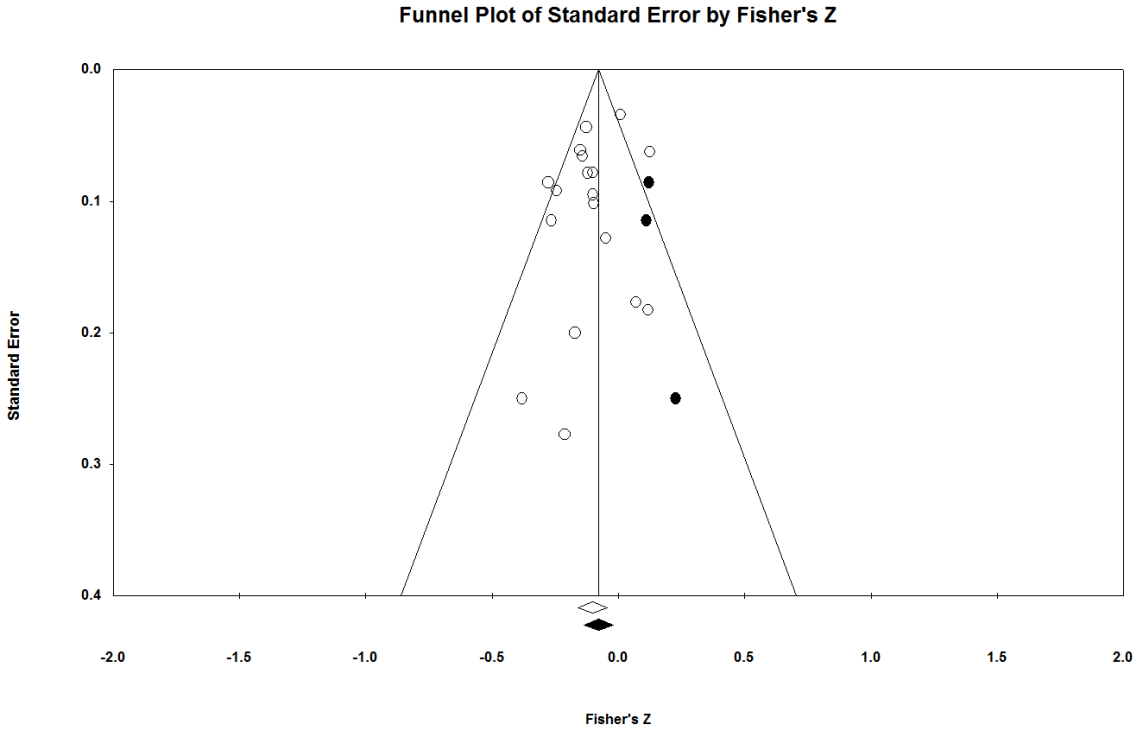


Figure 2.7. *Funnel Plot for Relation Between Physical Activity Total and Anxiety Sensitivity Physical Concerns*

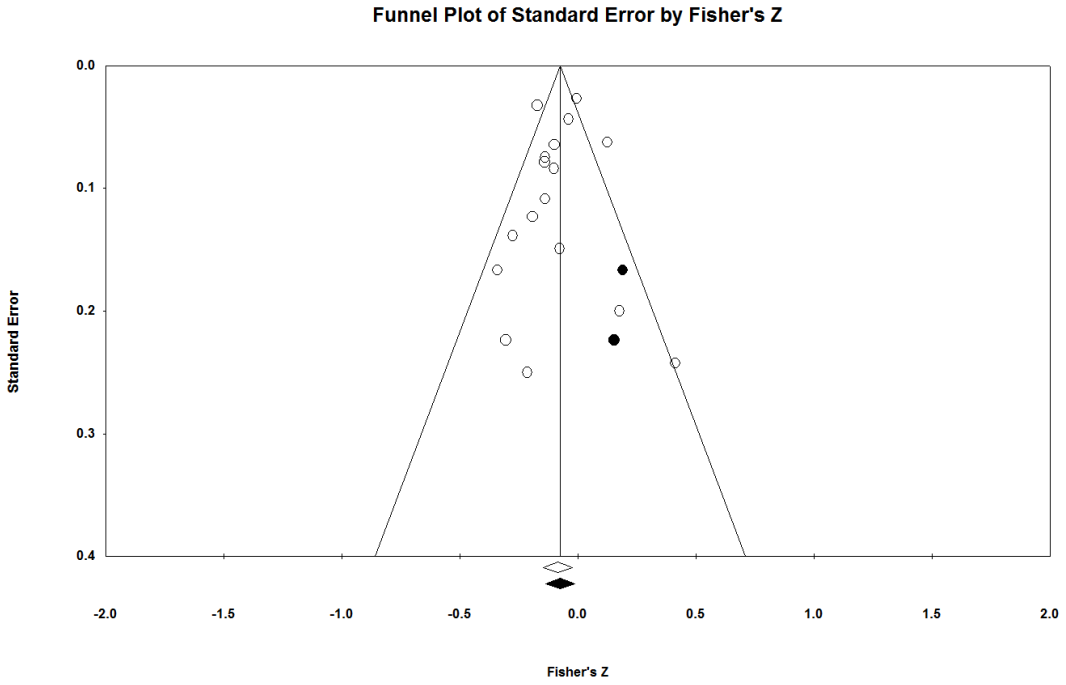


Figure 2.8. *Funnel Plot for Relation Between Physical Activity Total and Anxiety Sensitivity Cognitive Concerns*

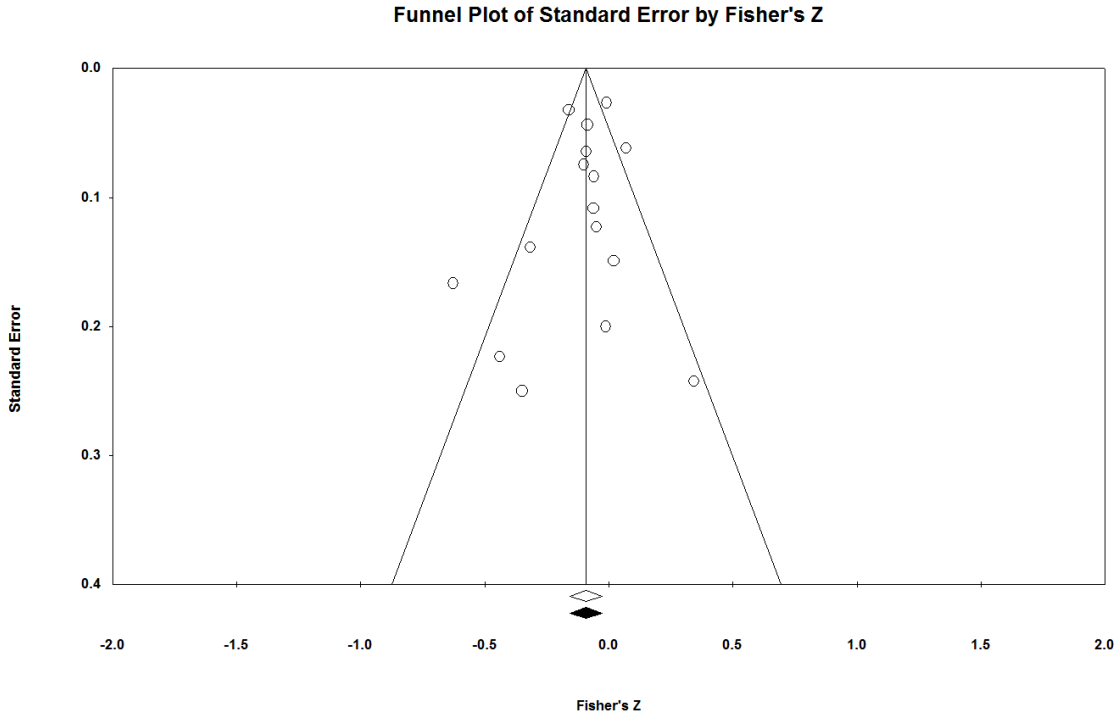
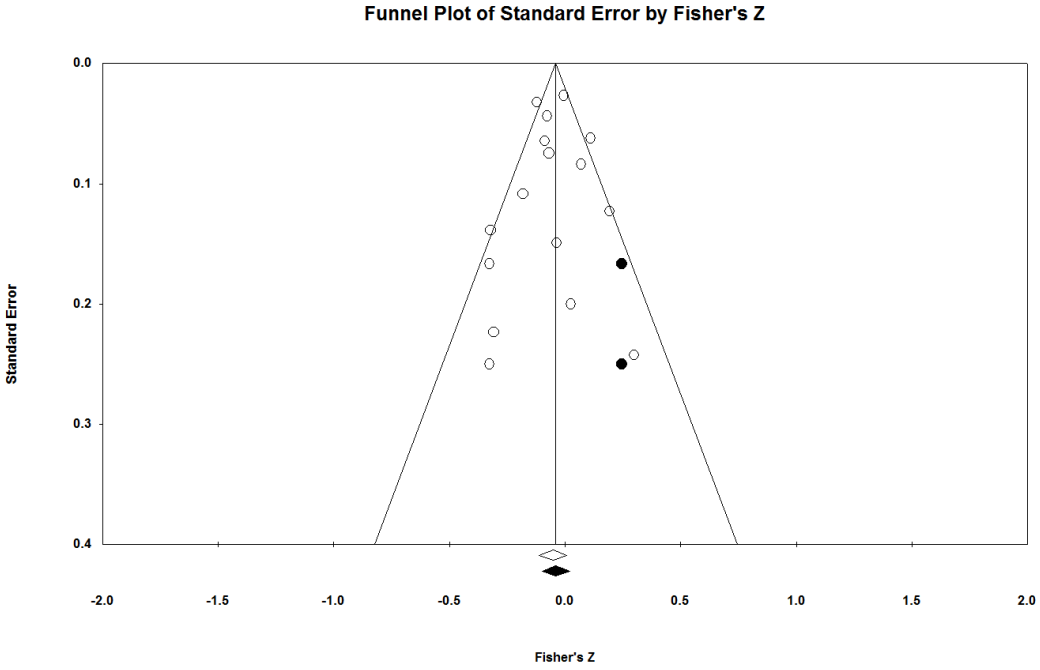


Figure 2.9. *Funnel Plot for Relation Between Physical Activity Total and Anxiety Sensitivity Social Concerns*



CHAPTER 3. BRIDGE BETWEEN STUDY 1 AND STUDY 2

As stated in the introduction to Study 1, previous literature on the anxiety sensitivity–physical activity relation has produced mixed results. It was evident that some clarification of the literature was needed to guide further research on anxiety sensitivity and physical activity. The results of Study 1 showed that a significant inverse relationship does exist between anxiety sensitivity and physical activity. By adding more robust evidence of this relationship, Study 1 supported further exploration of various implications of this relationship.

A likely contributing factor to the inverse relationship between anxiety sensitivity and physical activity is that anxiety sensitivity serves as a barrier to physical activity participation. Indeed, Moshier and colleagues (2016) examined the role of anxiety sensitivity in exercise goal attainment. Participants in their study expressed an interest in increasing their current levels of physical activity and set goals to increase their physical activity over the following week. At one week follow up, anxiety sensitivity was a significant predictor of past week physical activity after controlling for baseline physical activity levels. Specifically, individuals with higher (vs lower) levels of anxiety sensitivity made less progress towards their exercise goals. Surprisingly, anxiety sensitivity was the only such predictor and other variables associated with behaviour change (e.g., impulsivity, grit) were unrelated to change in physical activity. This study highlighted how anxiety sensitivity can prospectively interfere with physical activity levels, even in individuals who intend to increase their physical activity levels.

Group Differences in Physical Activity

Given the inverse relation between anxiety sensitivity and physical activity shown in Study 1, Study 2 sought to test if anxiety sensitivity could help to explain, at least in part, existing group differences in physical activity levels. This research question required a

mediational model to be tested, rather than moderation used in Study 1. Previous research testing anxiety sensitivity as a mediator to explain physical activity differences has shown that anxiety sensitivity mediates the links of anxiety, depression, and somatization with lower physical activity (Broman-Fulks et al., 2018). In other words, symptoms of anxiety, depression, and somatization are associated with increased anxiety sensitivity and their associations with anxiety sensitivity contribute to lower levels of physical activity.

There are several group differences in physical activity levels that may be impacted by anxiety sensitivity. Accelerometer data from the United States show that women have lower levels of physical activity levels than men. The same data also shows that physical activity levels drop from children to adolescents and from adolescents to adults (Troiano et al., 2008). There is also evidence of a positive relationship between socioeconomic status and physical activity levels (Stalsberg & Pedersen, 2010). Clearly all these differences are concerning and each warrant research attention. However, the gender gap in physical activity levels appeared to be particularly relevant given the relationship between anxiety sensitivity and gender, where women tend to have higher levels of anxiety sensitivity than men (Stewart et al., 1997).

Anxiety Sensitivity and Sex/Gender

Note that in this research previous studies have done a poor job clearly distinguishing between sex and gender and at times these words have been used interchangeably. A clear definition of the terms and labels used is not always present. This creates difficulty when interpreting this literature. To address this difficulty when reviewing the literature, an attempt was made to follow the terms used by authors (i.e., sex or gender), regardless of the congruence with the labels (e.g., male/female, men/women).

Additionally, Study 1 found that sex was not a significant moderator of the relation between anxiety sensitivity and physical activity. In other words, the magnitude of the anxiety sensitivity–physical activity relation is consistent across sex. Despite this null *moderation* effect, it is possible that a *mediating* effect exists among anxiety sensitivity, physical activity, and sex/gender. Specifically, anxiety sensitivity may mediate gender differences in physical activity levels due to the elevated amounts in women, rather than anxiety sensitivity having a different relation with physical activity across gender. Moderation assesses the strength of the relationship across levels another variable, whereas mediation assesses a potential mechanism of a relation.

Several studies have established sex and/or gender differences in anxiety sensitivity levels, where females have elevated levels compared to males. For example, Stewart (1997) found that women had elevated global anxiety sensitivity scores compared to men. When examining differences in anxiety sensitivity domains, they found a significant difference in the physical concerns factor, again, with women having higher levels than men. A similar pattern of results was found in another study using a child population (Walsh et al., 2004). This research suggests that the physical component of anxiety sensitivity is a primary contributor to gender differences in physical activity levels. This is relevant given that the physical component is the dimension most theoretically associated with physical activity levels. Indeed, we saw a significant relationship between physical activity levels and both anxiety sensitivity physical concerns and cognitive concerns, but not social concerns, in Study 1.

Research has shown that anxiety sensitivity is a contributing factor to gender differences in various health related outcomes. Meta-analytic findings have shown that there is a larger discrepancy in anxiety sensitivity between anxiety-related clinical and non-clinical samples when the samples have a larger percentage of females (Olatunji & Wolitzky-Taylor, 2009). Anxiety

sensitivity has also been shown to mediate gender differences in anxiety and depression (Norr et al., 2015). When examining the mediating role of anxiety sensitivity domains, anxiety sensitivity physical concerns and social concerns mediated gender differences in anxiety, while anxiety sensitivity cognitive concerns mediated gender differences in depression. Additionally, anxiety sensitivity has been shown to mediate gender differences in post-concussive symptoms (Albanese et al., 2017), and post-traumatic stress disorder symptoms (Norr et al., 2016). Although clear implications of anxiety sensitivity in sex/gender differences in various health outcomes is established, the mediating role anxiety sensitivity has in gender differences in physical activity had not been examined.

Anxiety Sensitivity, Sex/Gender, and Physical Activity

In Study 1, the percentage of sample that was female was not a significant moderator of the anxiety sensitivity–physical activity relationship. Nonetheless, there have been several studies that have shown significant effects involving gender, physical activity, and anxiety sensitivity. Indeed, some studies on anxiety sensitivity and physical activity have specifically focused on women-only samples (Olthuis et al., 2020; Sabourin et al., 2011). McWilliams and Asmundson (2001) examined the anxiety sensitivity–physical activity relationship separately for men and women. They found that anxiety sensitivity was significantly and inversely related to weekly frequency of exercise bouts for men, but not for women. This is consistent with a recent study showing total weekly physical activity time and anxiety sensitivity are negatively related for men but not women (Gomez et al., 2021). Interestingly, this recent study also demonstrated a positive relationship between walking time and anxiety sensitivity for women only (Gomez et al., 2021). In another study, adding sex as a covariate impacted the results of the anxiety sensitivity-vigorous intensity physical activity relationship. This study found that anxiety

sensitivity and vigorous intensity physical activity had a negative relationship, but that this was no longer significant when controlling for sex. However, sex was still a significant predictor of physical activity levels above and beyond anxiety sensitivity (Moshier et al., 2013).

Furthermore, gender appears to be involved in the effect of physical activity on reducing anxiety sensitivity levels. Medina and colleagues (2014) found that gender moderated the impact of exercise on anxiety sensitivity. Specifically, they found that men tended to show greater initial reductions in anxiety sensitivity than women, but that reductions were similar across gender by the end of the intervention.

Specific Aims of Study 2

With the evidence from Study 1 that anxiety sensitivity and physical activity are significantly and inversely related, the purpose of Study 2 was to examine if anxiety sensitivity contributes to group differences in physical activity levels. One known group difference in physical activity levels is between genders, where women tend to engage in less physical activity than men. This difference was selected given how concerning this gender difference is, but also because of how several studies have shown various associations between combinations of anxiety sensitivity, gender, and physical activity.

Thus, the specific aim of Study 2 was to determine if gender differences in anxiety sensitivity mediated gender differences in physical activity levels. This study also aimed to replicate findings that anxiety sensitivity and physical activity are inversely related, that women tend to exercise less than men, and that women have elevated levels of anxiety sensitivity. This study was designed to provide novel contributions to understanding gender-specific barriers to physical activity levels, which in turn could inform efforts to reduce this concerning gender gap.

CHAPTER 4. STUDY 2: GENDER DIFFERENCES IN PHYSICAL ACTIVITY ARE PARTIALLY EXPLAINNED BY ANXIETY SENSITIVITY IN POST-SECONDARY STUDENTS

This is based on an accepted manuscript of an article published by Taylor & Francis in The Journal of American College Health on January 15th 2019, available online: http://wwww.tandfonline.com/10.1080/07448481.2018.1549048.

The version of the published manuscript included in this dissertation was updated to include dissertation committee members' feedback. Readers are advised that Christopher DeWolfe, under the supervision of Dr. Sherry Stewart and Dr. Margo Watt, was responsible for study design, data preparation, data analysis, interpretation of findings and writing of the manuscript. Christopher DeWolfe incorporated feedback from co-authors into the published version of the manuscript. The reference for this publication is: DeWolfe, C. E. J., Watt, M. C., Romero-Sanchiz, P., & Stewart, S. H. (2020). Gender differences in physical activity are partially explained by anxiety sensitivity in post-secondary students. *Journal of American College Health*, *68*(3), 219-222. https://doi.org/10.1080/07448481.2018.1549048

Abstract

Objective: Female post-secondary students typically engage in less physical activity than their male counterparts. Given that women tend to have greater anxiety sensitivity (i.e., fear of arousal-based body sensations) and anxiety sensitivity is inversely related to physical activity participation, this study sought to determine if anxiety sensitivity mediates gender differences in self-reported physical activity. Participants and Methods: A sample of 802 post-secondary students (78.1% women) completed the Anxiety Sensitivity Index – 3 and a Lifestyles Questionnaire in September 2017. Results: Women reported significantly less physical activity and significantly greater anxiety sensitivity. Anxiety sensitivity was significantly and inversely related to self-reported physical activity. A significant indirect effect of gender on physical activity via anxiety sensitivity was shown (B=5.56, SE=2.81, p<.05, *95% CI* [1.31, 12.78]) that indicated 8.43% gender differences in physical activity occurred via anxiety sensitivity. Conclusions: Results suggest that anxiety sensitivity partially explains gender differences in physical activity. Anxiety sensitivity reduction interventions might increase physical activity participation and reduce the existing gender gap.

Keywords: gender, physical activity, anxiety sensitivity, avoidance.

Introduction

Physical activity reduces the risk of cardiovascular disease, diabetes, depression, anxiety, and many more serious health issues (Warburton et al., 2006). Unfortunately, approximately 40% to 50% of post-secondary students fail to engage in the minimum amount of physical activity recommended (across various physical activity recommendations) to obtain such health benefits (Keating et al., 2005). Also concerning is the fact that female post-secondary students meet physical activity guidelines (i.e., 150 minutes of weekly moderate-intensity to vigorous-intensity physical activity in bouts longer than ten minutes) significantly less often than their male counterparts (Downs et al., 2014).

The literature to date suggests that perceived barriers to physical activity may be more influential on physical activity participation than perceived benefits, perhaps especially for women (Lovell et al., 2010; Sabourin et al., 2011). One such barrier is anxiety sensitivity – a fear of arousal-based bodily sensations arising from the belief that these sensations will have negative physical, psychological, or social consequences (Reiss, 1991). Theoretically, anxiety sensitivity is a barrier to physical activity because individuals high in anxiety sensitivity are fearful of, and thus tend to avoid, the arousal sensations engendered by physical activity. In support of this postulation, research has shown an inverse relationship between anxiety sensitivity and physical activity (e.g., past-month duration of physical activity, Sabourin et al., 2011).

Furthermore, there is evidence that women have higher anxiety sensitivity than men (Stewart et al., 1997), although this has not been found consistently (e.g., Osman et al., 2010). Gender differences in anxiety sensitivity have may be the result of heredity (i.e., increased heritability in women; Jang et al., 1999), neurophysiology (i.e., differences in neurophysiological response to anxiety sensitivity-related images; Allan et al., 2019) and/or learning (i.e., women

receiving greater reward for expressing somatic complaints; Stewart et al., 1997) Taken together, the findings from extant literature indicating that women typically engage in less physical activity than men (Trost et al., 2002), that anxiety sensitivity is inversely related to physical activity (Sabourin et al., 2011; McWilliams & Asmundson, 2001), and that women have higher levels of anxiety sensitivity than men (Stewart et al., 1997), suggest that anxiety sensitivity is a plausible mediator to help explain the gender differences in physical activity.

Recently, researchers have identified a need for studies that connect gender, physical activity, and psychosocial variables into a single model to help explain gender differences in physical activity (Edwards & Sackett, 2016). To address this need, this study aimed to determine if anxiety sensitivity mediates the gender–physical activity relationship in post-secondary students. In addition to being the first to test the indirect effect of gender on physical activity via anxiety sensitivity, the present study sought to replicate previous research showing gender differences in physical activity and anxiety sensitivity as well as the inverse relation between anxiety sensitivity and physical activity. Consistent with previous research, it was predicted that: women would report lower physical activity levels (Downs et al., 2014; Trost et al., 2002) and higher anxiety sensitivity (Stewart et al., 1997) than men; anxiety sensitivity would be inversely related to physical activity (Sabourin et al., 2011; McWilliams & Asmundson, 2001), and anxiety sensitivity would partially mediate gender differences in self-reported physical activity.

Method

Participants and Procedure

The research ethics board at the primary investigator's institution approved study procedures. A sample of 819 post-secondary students from an Eastern Canadian university was recruited using an online participant pool. This sample was selected for convenience. The

participant pool was open to students taking any psychology course. Participants completed an online informed consent form prior to participating in the study and were compensated with partial course credit. Seventeen participants were removed for missing data (gender = 4; physical activity = 2; anxiety sensitivity = 6; multiple missing variables = 5). Median replacement was used when two or less of the 18 items measuring anxiety sensitivity were missing (n = 10). A final sample of 802 (176 men, 626 women; *M (SD)* age = 20.02 (3.06) years) remained. The distribution of students by year of study is presented in Table 4.1. Each participant spent approximately 30 minutes completing online scales hosted on Sona Systems (n.d.) including measures of anxiety sensitivity, physical activity, and demographics.

Measures

Anxiety Sensitivity. Anxiety sensitivity was measured using the 18-item Anxiety Sensitivity Index – 3 (ASI–3; Taylor et al., 2007). For each item, the participant reports on a five-point Likert scale (*0 = very little; 4 = very much*) how much they agree with statements describing experiences of feared arousal sensations (e.g., "it scares me when my heart beats rapidly"). The ASI–3 had good internal consistency in the present sample (α = .93), and it has good test-retest reliability (12-week, r = .74; Olthuis, Watt, Mackinnon, et al., 2014).

Physical Activity. Physical activity was measured categorically using two multiple-choice items from an author-compiled Lifestyle Questionnaire that measures lifestyle-related behaviours and preferences. The first item assessed how many days in the past 30 the participant engaged in physical activity; the second assessed the average duration of the participant's usual physical activity session. Previous research has found moderate to strong test-retest ability across self-report physical activity measures in university students (Murphy et al., 2017).

Data Analysis

Prior to data analysis, responses to the physical activity items were converted from categorical to continuous scores, following a process used by Kuntsche and colleagues (2008). Using this process, categorial response options that are a range (e.g., 30 minutes to an hour) are converted to average between the upper and lower bound values (e.g., 45 minutes). For items with no upper bound (e.g., more than three hours) the lower bound value (e.g., three hours) plus half of the value between it and the previous response option is used. Subsequently, the two physical activity items were multiplied together to obtain minutes of physical activity in the past 30 days. The two physical activity items were significantly correlated, $r = .375$, $p < .01$. Due to the risk of physical activity data being zero-inflated, a visual inspection of the distribution of this data was conducted and revealed the data was not zero-inflated and analyses were determined accordingly.

Hayes' PROCESS Macro in SPSS was used to test the mediation model (Hayes, 2013). The independent variable was gender (woman = 0; man = 1), the dependent variable was self-reported physical activity, and the mediator was anxiety sensitivity. Bias-corrected bootstrap confidence intervals (95% confidence intervals, z = 5,000 bootstrap samples) were estimated. When the 95% confidence interval did not include zero, this was taken to indicate a statistically significant effect. From this model, the indirect effect was used to assess the main hypothesis, that is, whether AS mediates the gender–physical activity relation. The individual paths were used to assess secondary hypotheses.

Results

Means, standard deviations, and intercorrelations for all variables are presented in Table 4.2. The results of the mediation model (see Fig. 1) indicated that compared to men, women reported significantly less physical activity ($B = 60.33$, $SE = 24.21$, $p < .001$, *95% CI* [12.82,

107.85]), and significantly greater anxiety sensitivity (*B* = -2.86, *SE* = 1.20, $p < .05$, *95% CI* [-5.22, -0.50]). As well, anxiety sensitivity was significantly and inversely related to self-reported physical activity after controlling for gender (*B* = -1.95, *SE* = 0.71, $p < .01$, *95% CI* [-3.34, -0.55]). Finally, results revealed a significant indirect effect of gender on self-reported physical activity via anxiety sensitivity (*indirect effect* = 5.56, *SE* = 2.81, *95% CI* [1.31, 12.78]). Because gender was still associated with self-reported physical activity even after controlling anxiety sensitivity, this pattern indicates *partial* mediation of the relationship between gender and self-reported physical activity via anxiety sensitivity. The ratio of indirect effect to total effect was .0843.

Comment

The purpose of this study was to determine if anxiety sensitivity may help to explain the relationship between gender and physical activity in post-secondary students. As expected, results replicated previous findings that women report less physical activity than men (Downs et al., 2014; Trost et al., 2002), women report higher anxiety sensitivity than men (Stewart et al., 1997), and anxiety sensitivity is inversely associated with duration of physical activity (Sabourin et al., 2011). Consistent with our primary hypothesis, there was also a significant indirect effect of gender on physical activity via anxiety sensitivity. Taken together, these results provide a framework for connecting previous research showing that women typically engage in less physical activity than men, that women have greater anxiety sensitivity than men, and that increased anxiety sensitivity is associated with decreased physical activity levels.

There is evidence to suggest that post-secondary physical activity promotion efforts, especially those for women, should focus on removing the barriers to physical activity (Lovell et al., 2010; Sabourin et al., 2011). The present study replicated previous work by identifying that

anxiety sensitivity is a significant barrier to physical activity, suggesting that anxiety sensitivity reduction interventions could be used to increase physical activity. The novel mediation results of the present study suggest that such interventions may be particularly beneficial for women, as anxiety sensitivity was shown to be a mechanism through which women engage in lower levels of physical activity than men. Fortunately, anxiety sensitivity can be reduced in as little as a single session (Broman-Fulks & Storey, 2008). Single session anxiety sensitivity interventions that combine psychoeducation and interoceptive exposure can significantly reduce anxiety sensitivity and maintain compared to health-focused control interventions and maintain these reductions up to six months post-treatment (Keough & Schmidt, 2012). Moreover, cognitive-behavioural therapy has a moderate-to-large effect on reducing anxiety sensitivity in non-clinical high anxiety sensitivity samples (Smits, Berry, Tart, et al., 2008), suggesting that anxiety sensitivity interventions may be a potentially efficient and effective physical activity promotion strategy for post-secondary students. If anxiety sensitivity interventions can help an individual increase their physical activity levels, the increase in physical activity may have an added benefit of improving or maintaining the anxiety sensitivity reductions, given research showing physical activity reduces anxiety sensitivity (Broman-Fulks et al., 2004; Broman-Fulks & Storey, 2008; Smits, Berry, Rosenfield, et al., 2008).

Notably, the indirect effect via anxiety sensitivity only partially accounted for the gender–physical activity relation: 8.43% of the effect of gender on physical activity occurred indirectly via anxiety sensitivity. This is unsurprising, as multiple factors likely account for gender differences in physical activity Edwards and Sackett (2016) suggested that physical activity-related social support, self-efficacy, and motivation may help account for gender differences in physical activity, as research has noted lower levels of these factors in women and

in those who engage in less physical activity. Future research examining a multi-mediator model including these possible mediators along with anxiety sensitivity would further improve our understanding of the gender gap in physical activity. Nonetheless, our identification of one factor that contributes significantly to the gender differences in physical activity is an important step towards a more comprehensive model.

Limitations and Conclusions

Several study limitations should be acknowledged. First, our use of cross-sectional data to test mediation could be criticized (Maxwell et al., 2011). Others have argued, however, that mediation analyses can be conducted with cross-sectional data (Hayes, 2013). Although causality cannot be inferred, the indirect effect can still provide meaningful information. In fact, recently published research has used cross-sectional data to demonstrate that anxiety sensitivity mediates gender differences in anxiety and depression symptoms (Norr et al., 2015). Second, we used an author-compiled measure of physical activity that assessed the amount of exercise in the past 30 days. Issues with this measure include that it is a two-item self-report measure, relies on retrospective (versus prospective) self-report, and has not been previously validated. Although previous research has shown differences between objectively measured physical activity (e.g., using accelerometers) and self-reported physical activity, individuals with relatively higher education, such as the participants in the current study, have been shown to report their physical activity levels with acceptable accuracy (Winckers et al., 2015). An additional limitation with our physical activity measure, however, is that it does not measure physical activity by intensity, which is problematic given that previous research indicates that the anxiety sensitivity–physical activity relationship is moderated by physical activity intensity (Moshier et al., 2013). Given the AS–physical activity relationship appears to increase in magnitude with increasing physical

activity intensity, perhaps anxiety sensitivity contributes to gender differences for vigorous-intensity physical activity, but not low-intensity physical activity. Finally, our use of self-selected post-secondary students taking a psychology course warrants caution in generalizing the results beyond this population. Indeed, our sample over-represented women (approximately 78% female) compared to the gender composition of the entire university (approximately 55% female). Nonetheless, the sample included many students across the typical four-year time frame of degree completion. Despite these design, sampling, and measurement limitations, our findings are consistent with other research that has demonstrated an inverse relationship between anxiety sensitivity and physical activity (Sabourin et al., 2011; McWilliams & Asmundson, 2001; Moshier et al., 2013).

Future research can address the above limitations and add to the existing literature in several ways. First, research should examine the mediating role of anxiety sensitivity in the gender–physical activity relationship using a longitudinal design. Although many studies have looked at the relationship between anxiety sensitivity and physical activity (Sabourin et al., 2011; McWilliams & Asmundson, 2001; Moshier et al., 2013), to our knowledge researchers have not yet examined this relationship over time. A longitudinal study design would improve our understanding of the possibly bi-directional nature of the anxiety sensitivity–physical activity relationship. It would also allow causality to be determined in the role of anxiety sensitivity mediating gender differences in physical activity. Second, more research is needed to examine the anxiety sensitivity–physical activity relationship using objective measures of physical activity as few studies have employed this methodology (Hearon et al., 2014).

Overall, the findings of the current study address a need to better understand physical inactivity, a major health concern facing many post-secondary students – particularly women

(Downs et al., 2014). Our results improve our understanding of anxiety sensitivity as a barrier physical activity broadly. They also provide insight as to why a concerning gender discrepancy in physical activity exists and suggest that anxiety sensitivity reduction interventions may help to reduce this gender gap in physical activity. This study addresses the need for research on physical activity barriers, particularly for women and those high in anxiety sensitivity (Sabourin et al., 2011). Our results may ultimately contribute to improving efforts to help students receive the many mental and physical health benefits of physical activity (Warburton et al., 2006).

Table 4.1. *Number of Participants by Year of Study*

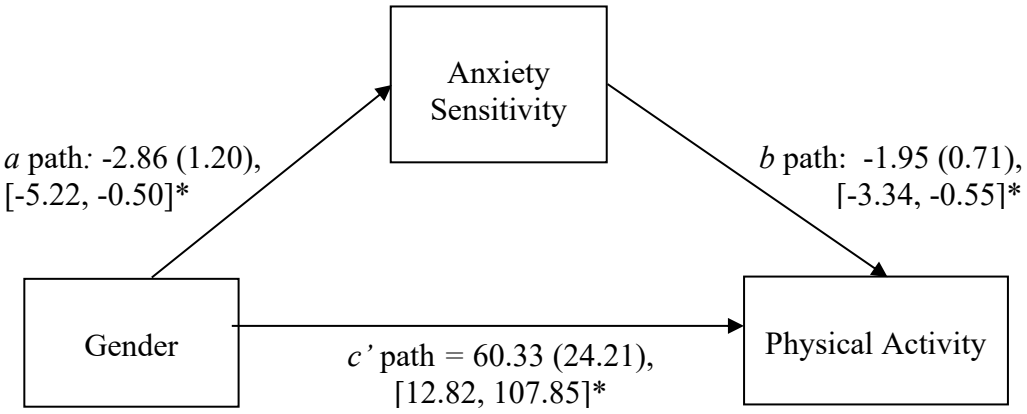
Year of Study	*n*	% of Total Sample
First	280	34.91
Second	230	28.68
Third	119	14.84
Fourth	135	16.84
Fifth	26	3.24
Sixth	7	0.87
Did Not Report	5	0.62
Total	**802**	**100**

Table 4.2. *Means (and Standard Deviations) and Intercorrelations for Each Variable*

	1	2	3	Women	Men	Total
1. Gender	-			*n* =626(78.1%)	*n*=176(21.9%)	*N*=802(100.0%)
2. ASI–3	-.084*	-		20.23(14.65)	17.38(11.89)	19.60(14.13)
3. PA	.096*	-.104*	-	348.25(281.60)	414.14(291.85)	362.71(285.01)

Note. Gender was coded as 0 = women; 1 = men. ASI–3 = Anxiety Sensitivity Index – 3 score. PA = minutes of physical activity in the past 30 days; * $p < .01$.

Figure 4.1. *Mediation Model: Indirect Effect of Gender on Physical Activity via Anxiety Sensitivity.*



Indirect effect = 5.56, *SE* = 2.81, [1.31, 12.78]*

Unstandardized coefficients, standard errors, and bootstrapped 95% confidence intervals are reported. Gender was coded as 0 = women; 1 = men. *Significant path (95% CI does not include 0).

CHAPTER 5. BRIDGE BETWEEN STUDY 2 AND STUDY 3

The results from Study 1 clarified that anxiety sensitivity and physical activity have an inverse relationship across the extant literature. Study 1 showed that this relationship remains consistent across a variety of moderators assessed (e.g., anxiety sensitivity measure used, type of physical activity assessed). With an established relationship between anxiety sensitivity and physical activity, Study 2 examined if anxiety sensitivity helps explain the known and concerning gap in physical activity levels between men and women. Study 2 provided evidence that gender differences in anxiety sensitivity partially explain this gender gap in physically activity levels. Taken together, these studies demonstrated that anxiety sensitivity is an important variable to consider when examining physical activity levels.

The connection between anxiety sensitivity and physical activity is also apparent when examining anxiety sensitivity interventions. Exercise is a key component of intervention protocols for anxiety sensitivity because it serves as a form of interoceptive exposure (Olthuis, Watt, Mackinnon, et al., 2014; Stewart & Watt, 2008). In other words, exercise provides an opportunity to experience feared arousal-based body sensations in a safe context. In fact, exercise is an effective stand-alone intervention for reducing anxiety sensitivity and associated mental health symptoms (Olthuis et al., 2020).

A primary reason that anxiety sensitivity is a valuable treatment target is because of its transdiagnostic properties. More specifically, anxiety sensitivity is an important clinical tool because it is a risk and/or maintenance factor across a variety of mental health disorders. These include panic disorder, social anxiety disorder, generalized anxiety disorder, and major depressive disorder (Olatunji & Wolitzky-Taylor, 2009). With high rates of comorbidity in mental health (Barr et al., 2022) the ability to target shared underlying risk factors and reduce

symptoms across disorders is important. One randomized controlled trial found that a single session of exercise reduced anxiety sensitivity, but not distress tolerance or intolerance of uncertainty, two alternative constructs with established transdiagnostic properties (LeBouthillier & Asmundson, 2015). These results suggest that physical activity has a unique relationship with anxiety sensitivity when compared to other transdiagnostic constructs.

Despite the value of anxiety sensitivity as a transdiagnostic construct and potential unique association it has with physical activity when compared to other transdiagnostic constructs, Study 1 and Study 2 did not examine the transdiagnostic nature of anxiety sensitivity and how it may relate to physical activity. The only component of the present dissertation to this point that considered the role of mental health was where Study 1 suggested that mental health status may moderate the anxiety sensitivity–physical activity relationship. For the final study of this dissertation, it was important to bridge this gap by exploring the transdiagnostic properties of anxiety sensitivity in the context of physical activity, broadly speaking.

Previous research has already examined the mediating role of anxiety sensitivity between physical activity levels and mental health symptoms. Anxiety sensitivity has been shown to mediate the relationships between exercise frequency and anxiety, depression, as well as somatization. Specifically, results suggest that increased physical activity reduces symptoms of anxiety and depression through reductions in anxiety sensitivity. Additional analyses in the same study showed varied results according to anxiety sensitivity subscale scores. These results indicated all three subscales, physical concerns, cognitive concerns, and social concerns mediated the exercise frequency–anxiety relationship. Regarding depression, only cognitive concerns and social concerns were significant mediators. Finally, physical concerns and cognitive concerns were significant mediators between physical activity levels and somatization

(Broman-Fulks et al., 2018). Furthermore, research had shown that interventions involving a physical activity component can reduce anxiety sensitivity and associated mental health symptoms (Olthuis, Watt, Mackinnon, et al., 2014). One question remaining is: does anxiety sensitivity predict mental health symptoms in populations with a high level of physical activity?

As shown in the studies included in the meta-analysis in Study 1, most research on physical activity, anxiety sensitivity, and mental health symptoms has heavily focused on the following populations: a) individuals who engage in low amounts of physical activity; b) individuals with elevated anxiety sensitivity levels; c) individuals with elevated mental health concerns; and/or d) community or general population samples. With results from Study 1 showing that individuals high in anxiety sensitivity engage in lower levels of physical activity, research showing that individuals with various mental health concerns engage in lower levels of physical activity (De Mello et al., 2013; Vancampfort et al., 2017), and the low levels of physical activity in the general population (e.g., Canadian data suggesting only 15% of the population achieve recommended dose of 150 weekly minutes of moderate to vigorous physical activity; Colley et al., 2011), it became apparent that this research has largely focused on populations that engage in lower levels of physical activity. Thus, examining the relationship between anxiety sensitivity and mental health in a highly physically active population in my final dissertation study (Study 3) addressed a gap in the literature.

Athletes are perhaps the clearest example of a population defined by engaging in elevated amounts of physical activity. Interestingly, athletes have comparable levels of mental health concerns to non-athletes (Gorczynski et al., 2017; Rice et al., 2019; Chapa et al., 2022) while at the same time having lower levels of anxiety sensitivity (DeWolfe et al., 2022). Since athletes have lower anxiety sensitivity levels and comparable levels of mental health problems, Study 3

sought to determine if anxiety sensitivity was a predictor of mental health outcomes in athletes. In previous work, it was shown that military personnel had lower levels of anxiety sensitivity than the general population but that anxiety sensitivity was still a predictor of panic attacks (Schmidt et al., 1997; Schmidt et al., 1999). As well, it is important to consider that athletes may have different experiences with arousal sensations which may impact anxiety sensitivity and its association with mental health. This includes physiological differences associated with increased physical fitness, increased exposure to arousal in the form of physical activity, and often experiencing arousal in social contexts (e.g., playing sports in the presence of others).

Although there have been increased efforts towards athlete mental health research in recent years, more work is needed (Rice et al., 2016). One major gap in this space is the need for transdiagnostic treatment targets in athletes (Ekelund et al., 2022). Research on anxiety sensitivity in athletes has focused on performance (Molina et al., 2014) and physical health (Caze et al., 2021; Wilson et al., 2021). At present, the relationship between anxiety sensitivity and mental health symptoms in athletes remains a novel and potentially highly valuable field of study.

Overall, the focus of Study 3 was to examine the relationship between anxiety sensitivity and mental health symptoms in athletes. With anxiety sensitivity most strongly linked to emotional disorder symptoms (Naragon-Gainey, 2010; Olatunji & Wolitzky-Taylor, 2009), Study 3 focused on emotional disorder symptoms. As such, Study 3 served two important purposes. First, Study 3 aimed to add to the literature on anxiety sensitivity and physical activity by examining the transdiagnostic properties of anxiety sensitivity in a highly physically active athlete sample of varsity athletes. Second, Study 3 served to address the need for evidence-based transdiagnostic factors in athlete populations.

CHAPTER 6. STUDY 3: MENTAL HEALTH IN ATHLETES: ANXIETY SENSITIVITY AS A TRANSDIAGNOSTIC RISK FACTOR

The manuscript prepared for this study is presented below. Readers are advised that Christopher DeWolfe, under the supervision of Dr. Sherry Stewart and Dr. Margo Watt, was responsible for data preparation, data analysis, interpretation of findings and writing of the manuscript. Christopher was a collaborator in study design and data collection. Christopher incorporated feedback from co-authors. Christopher submitted a paper based on this manuscript on July 5th 2023. The current reference for this paper is: DeWolfe, C. E. J., Watt, M. C., Galbraith, M. K., Olthuis, J. V., & Stewart, S. H. (2023). *Mental health in athletes: Anxiety sensitivity as a transdiagnostic risk factor* [Manuscript submitted for publication]. Department of Psychology and Neuroscience, Dalhousie University.

Abstract

The concerning rates of mental health issues in the general population exist in athlete populations. At the same time, it cannot be assumed that mental health findings from general populations apply to athletes given their sport-specific stressors (e.g., sport-related concussion, overtraining) and protective factors (e.g., increased physical activity). This study aimed to address the pressing need to identify transdiagnostic mental health risk factors in athletes. Varsity athletes ($N = 244$; $M_{age} = 19.91$ years; 48% female) completed predictor measures of anxiety sensitivity and neuroticism, and outcome measures of generalized anxiety, social anxiety, depression, and panic attacks. Results revealed that anxiety sensitivity was associated with emotional disorder symptoms in athletes, as seen in prior literature with non-athlete samples, and that these relationships persisted when controlling for neuroticism. Regarding anxiety sensitivity domains, social concerns uniquely predicted social anxiety symptoms while both cognitive and social concerns uniquely predicted symptoms of generalized anxiety and depression. Overall, this study provides initial support for the potential utility of anxiety sensitivity as a transdiagnostic treatment target in athletes.

Keywords: anxiety sensitivity; athlete; mental health; anxiety; transdiagnostic.

Introduction

Data from the National Institute of Mental Health in the United States (2022) indicate that, of various developmental levels, emerging adults aged 18–25 years, have the highest past year prevalence of any mental illness at 30.6%. This is higher than for young and middle-aged adults 26–49 years old (25.3%) and adults 50 years and older (14.5%). In line with this finding, post-secondary students, who are typically in the emerging adult age range, experience high rates of mental health concerns. In a survey of 21 countries, the 12-month prevalence rate of university students having a diagnosed mental health condition was 20.3% (Auerbach et al., 2016). Only 16.4% of those with a mental health condition reported receiving minimally acceptable treatment (i.e., at least four visits in past 12 months to any type of treatment provider, at least two visits to a treatment provider and using medication for emotional problems, or current treatment participation) in the past year (Auerbach et al., 2016).

Consistent with mental health concerns broadly, specific concerns have been raised about mental health problems in athletes (e.g., Gouttebarge et al., 2019). In a sample of college student athletes, 26% reported moderate or greater stress levels, 25% reported moderate or greater anxiety symptoms, and 23% reported moderate or greater depression symptoms (Beiter et al., 2015). University athletes appear to experience depressive symptoms (Gorczynski et al., 2017) and anxiety symptoms (Rice et al., 2019) at comparably high rates to university non-athletes.

Despite their concerningly high levels of these emotional disorder symptoms, there is an identified need for athlete-specific studies as they may have unique experience with mental health difficulties (Hughes & Leavey, 2012; Reardon & Factor, 2010; Rice et al., 2016). The lack of athlete-specific research is problematic given that there are several factors related to participation in sports that may impact the development of mental health symptoms (Rice et al.,

2016). For instance, depression has been linked with sport-specific stressors such as overtraining (Meeusen et al., 2013) and sport-related concussion (Rice et al., 2018). As well, student athletes have increased drinking levels compared to the already elevated rates of non-athlete students (Martens et al., 2006). Student athletes also have increased negative consequences associated with drinking (Martens et al., 2006). These are just some of the factors that show that athlete mental health may differ in some ways from non-athletes.

Additionally, student-athletes are less likely than their non-athlete student counterparts to access mental health services (Edwards et al., 2021). Athletes' barriers to accessing mental health treatment include a lack of free time for seeking services, fear of stigma, and a fear of appearing mentally weak (López & Levy, 2013). Thus, research specifically focused on athlete mental health can be used to help optimize their mental health treatment. For example, athlete-specific results can be used to provide psychoeducation to athletes to overcome stigma. Furthermore, athletes report a strong preference for clinicians who are knowledgeable about sport and sport-related issues (López & Levy, 2013). Additional athlete-specific research is needed to help inform clinicians of athlete-specific factors associated with mental health.

One challenge when attempting to address mental health concerns, whether for athletes or non-athletes, is the very high rate of diagnostic comorbidity. In one large-scale study, it was estimated that 54% of individuals who met criteria for one mental health diagnosis also met criteria for a comorbid mental health condition (Barr et al., 2022). When disorder-specific approaches are prioritized, comorbidity presents a variety of challenges for clinicians. This includes comorbidity not being well explained by disorder-specific theories, creating difficulty identifying which specific concern to prioritize, and increased burden on clinicians (e.g., having to learn/implement a variety of treatments, increased difficulty implementing group-based

treatment; Taylor & Clark, 2009). This has led to the exploration of transdiagnostic targets for mental health interventions (i.e., vulnerability factors that contribute to the development and maintenance of more than one mental health disorder and help explain their overlap). A benefit of transdiagnostic treatment approaches is that a single approach can be used to reduce symptoms across multiple disorders (Schaeuffele et al., 2021). However, even though the need for transdiagnostic approaches to mental health among athletes has been identified (Ekelund et al., 2022), research on transdiagnostic approaches in athlete samples is scarce.

One transdiagnostic treatment target well-validated outside of the student athlete population is anxiety sensitivity. It involves a fear of anxiety experiences and arousal-based body sensations that arises due to catastrophizing about the consequences of these experiences and sensations (Reiss & McNally, 1985). An individual with elevated anxiety sensitivity may experience racing thoughts, for example, and catastrophize that these sensations are indicators of them "going crazy". Anxiety sensitivity is comprised of three sub-dimensions (Taylor et al., 2007): a physical concerns dimension involving fear of physical anxiety sensations (e.g., increased heart rate) due to beliefs that they will result in physical catastrophe (e.g., heart attack); a cognitive concerns dimension consisting of fear of cognitive anxiety sensations (e.g., difficulty concentrating) due to beliefs that they will result in psychological catastrophe (e.g., loss of control); and a social concerns dimension associated with fear of displaying observable anxiety sensations (e.g., sweating) due to beliefs that they will result in social catastrophe (e.g., ridicule by others).

In samples not selected for athlete status, anxiety sensitivity is associated with the presence and severity of a variety of emotional disorders (i.e., individuals with emotional disorder diagnoses tend to have higher levels of anxiety sensitivity, and anxiety sensitivity has a

positive relation with symptoms of various emotional disorders) including panic disorder, social anxiety disorder, generalized anxiety disorder, and major depressive disorder (Olatunji & Wolitzky-Taylor, 2009). Naturally occurring reductions in anxiety sensitivity over time are related to reductions in anxiety symptoms over time (Hovenkamp-Hermelink et al., 2019). Fortunately, anxiety sensitivity-targeted interventions have been shown to be effective not only in reducing anxiety sensitivity, but also in reducing symptoms across anxiety-related disorders such as panic and social anxiety disorders (Olthuis, Watt, & Stewart, 2014).

Research in non-athlete samples has shown that the three sub-dimensions of anxiety sensitivity (physical, social, and cognitive concerns) have unique associations with mental health concerns (e.g., Allan, Capron et al., 2014; Intrieri & Newell, 2022; Naragon-Gainey, 2010; Olthuis, Watt, & Stewart, 2014; Saulnier et al., 2018). For example, Olthuis, Watt, and Stewart (2014) assessed the unique value of each of the three sub-domains of anxiety sensitivity in predicting symptoms of several emotional disorders, including social anxiety, worry, panic, and depression, in a treatment-seeking sample with high anxiety sensitivity. Their results indicated that: a) the physical concerns dimension was the only anxiety sensitivity domain to uniquely predict symptoms of panic; b) only the cognitive concerns dimension predicted symptoms of depression above-and-beyond the other anxiety sensitivity dimensions; and c) the social concerns subscale and cognitive concerns subscale each significantly predicted unique variance in social anxiety symptoms. In another sample of treatment-seeking individuals (Allan, Capron, et al., 2014), each anxiety sensitivity sub-dimension had unique relationships with several emotional disorder symptom domains (e.g., cognitive concerns with generalized anxiety disorder and major depressive disorder; physical concerns with panic disorder; social concerns with social anxiety disorder). Meta-analytic results have shown that cognitive concerns are most strongly associated

with depression and post-traumatic stress symptoms, physical and cognitive concerns are most strongly associated with panic symptoms, physical concerns are most strongly associated with symptoms of agoraphobia, social concerns are most strongly associated with social anxiety, and cognitive and social concerns are most strongly associated with generalized anxiety symptoms (Naragon-Gainey, 2010). Taken together, these results demonstrate the added value that more specific anxiety sensitivity dimensions provide in the prediction of various emotional disorder symptom outcomes.

Unfortunately, research examining anxiety sensitivity in athletes is limited. Recent research has shown that athletes have significantly lower levels of global anxiety sensitivity, anxiety sensitivity physical concerns, and anxiety sensitivity social concerns, but not anxiety sensitivity cognitive concerns, when compared to non-athletes (DeWolfe et al., 2022). The available research with athlete populations has yet to examine the relationship between anxiety sensitivity and mental health outcomes. Studies investigating anxiety sensitivity in athletes have instead focused on anxiety sensitivity's links to physical health (e.g., Caze et al., 2021; Wilson et al., 2021) and performance-related variables (e.g., Molina et al., 2014). Such research has shown, for example, that anxiety sensitivity contributes to poorer sport performance in high-pressure situations (Molina et al., 2014) and that anxiety sensitivity physical concerns was the only anxiety sensitivity component associated with greater initial symptom reporting in athletes with sport-related concussions (Caze et al., 2021).

Athlete-specific anxiety sensitivity research is needed given athletes' elevated levels of physical activity. On the one hand, since physical activity reduces anxiety sensitivity (Broman-Fulks et al., 2004; Olthuis et al., 2020), athletes' high levels of physical activity may dampen the anxiety sensitivity-emotional disorder symptoms relationship. On the other hand, previous

studies on military cadets demonstrated that despite lower levels of anxiety sensitivity than the general population, anxiety sensitivity was still a prospective predictor of the development of panic attacks in this population during stressful basic training (Schmidt et al., 1997; Schmidt et al., 1999). When applied to athletes, this work would suggest that despite their lower levels of anxiety sensitivity relative to the general population (DeWolfe et al., 2022), athletes may well still show important positive relations between anxiety sensitivity and symptoms of various emotional disorders.

In association with their increased levels of exercise, athletes have been shown to have other differences that may impact the anxiety sensitivity-emotional disorder symptoms relation. For instance, athletes have greater physical fitness, a higher VO_2 max, lower resting heart rate, and greater heart rate variability than non-athletes (Mendes et al., 2019; Pakkala et al., 2005). These physiological characteristics may differentially impact athletes experience of arousal-based sensations and thus the way anxiety sensitivity operates in non-athletes may not be generalizable to athletes. Additionally, with increased physical fitness, athletes are at a reduced risk for adverse health events (e.g., cardiovascular disease; Warburton et al., 2006), which may buffer against catastrophizing about the consequences of arousal sensations. Furthermore, research has shown that athletes have higher levels of sensation seeking and associated risk taking than non-athletes (Mastroleo et al., 2013), which may impact the anxiety sensitivity–emotional disorder symptoms relation given differences in how anxiety sensitivity and sensation seeking relate to various emotional problems (Castellanos-Ryan et al., 2013).

Given the identified need for research examining transdiagnostic approaches to mental health in athletes (Ekelund et al., 2022) and that anxiety sensitivity is an established transdiagnostic risk factor outside of athlete samples (Olatunji & Wolitzky-Taylor, 2009;

Olthuis, Watt, & Stewart, 2014), we sought to examine the ability of global anxiety sensitivity and its three dimensions to predict a variety of emotional disorder symptoms in athletes (i.e., social anxiety, generalized anxiety, depression, and panic symptoms). Specific aims of the present study were threefold. First, we sought to assess if anxiety sensitivity is related to emotional disorder symptoms (i.e., social anxiety, generalized anxiety, depression, and panic attacks) in athletes. Given the strong relationship anxiety sensitivity has with the higher-order trait of neuroticism (i.e., a tendency to experience negative affect such as anxiety and depression across situations; Cox et al., 1999), it has been argued that neuroticism should be controlled for when examining the associations between anxiety sensitivity and various health outcomes (e.g., Yunus et al., 2022). Thus, the second aim of this study was to determine if athletes' global anxiety sensitivity levels predict unique variance in mental health symptoms above-and-beyond neuroticism. Third, we examined if each of the three anxiety sensitivity dimensions predicts unique variance in specific emotional disorder symptoms in athletes above the other anxiety sensitivity dimensions. Based on previous research, we predicted that global anxiety sensitivity would be significantly and positively related with symptoms of social anxiety symptoms, generalized anxiety, depression, and panic (Allan et al., 2015; Olatunji & Wolitzky-Taylor, 2009) and that each of these significant associations would be maintained when controlling for neuroticism (Yunus et al., 2022). Furthermore, we predicted that each of the three anxiety sensitivity dimensions would uniquely predict variance in specific emotional disorder symptoms above-and-beyond the variance predicted by the other two anxiety sensitivity domains. Specifically, we hypothesized that anxiety sensitivity social concerns would uniquely predict social anxiety disorder symptoms, anxiety sensitivity cognitive concerns would uniquely predict

depression, generalized anxiety symptoms and panic, and anxiety sensitivity physical concerns would uniquely predict panic (Olthuis, Watt, & Stewart, 2014; Allan, Capron, et al., 2014).

Methods

Power Analysis

An a priori power analysis Using G*Power 3.1 was conducted to determine a sufficient sample size. The power analysis assessed the sample size needed to detect a multiple regression R^2 increase with a model having three total predictors and detecting the effect of adding one predictor. This was selected as the closest model to detecting the significance of a single anxiety sensitivity subscale above and beyond the others (i.e., the likely smallest effect we were trying to detect). Effect size f^2 was determined to be .09 based on .08 as the variance explained by the special effect and .85 as the residual variance. These assumptions were based on values from Olthuis, Watt, and Stewart (2014) who assessed the unique contributions of anxiety sensitivity subscales in predicting mental health symptoms. With an alpha value of .05 and power of .95, it was determined that a sample size of at least N=141 was needed.

Participants

The data for the present study come from an annual data collection on athlete mental health conducted at a single rural Eastern Canadian university. The data was collected over a three-year period with three cohorts. Data from the first year of data collection could not be used as the measures differed slightly in year one compared to the following two years. Thus, the present study used the data from the second year of data collection (n= 216) and, to maximize power, students who were in their first year of study during the third year of data collection (n=28). Participants in the larger study were not identifiable across years, so this approach maximized power while eliminating the possibility of the same participant being included twice.

This resulted in 244 participants total. Mean age was 19.9 (*SD*=1.9) years. The sample was relatively sex balanced (48% female, 52% male). From most to least prevalent, participants identified their race/ethnicity as White (81.1%), Black (7.4%), Indigenous (2.9%), Asian (2.5%), and Hispanic (0.4%); an additional 3.3% identified as Mixed race, 1.6% identified as "other", and 0.8% did not report on their racial/ethnic background. Mean year of study was 2.4 (*SD*=1.4) years. Participants were recruited from the following teams: men's and women's basketball, cross country, hockey, soccer, and track and field, as well as men's football and women's rugby. In year two of data collection, 12/12 varsity teams at the university where the study took place were represented; in year three, 9/12 teams were represented.

Procedure

Following research ethics board approval, coaches representing each of the varsity teams at the participating university were invited via email to have their team take part in a study on athlete mental health. Teams with coaches that expressed interest were provided with an in-person presentation during their training camp that provided an overview of the study and an opportunity for questions. Athletes who expressed interested were provided an email with a link to complete consent forms and questionnaires online.

Measures

Demographic Questionnaire. Participants completed an author-compiled demographics questionnaire. This included questions regarding age, sex, race/ethnicity, and year of study.

Anxiety Sensitivity Index – 3. The Anxiety Sensitivity Index – 3(ASI–3; Taylor et al., 2007) is an 18-item self-report measure that assesses global anxiety sensitivity levels through a total score as well as physical, cognitive, and social concerns domains through three 6-item subscales. For each item, participants reported on a 5-point scale (0 = *very little*; 4 = *very much*)

how much they agreed with various items that indicated fears of anxiety experiences and arousal-based sensations (e.g., “When my chest feels tight, I get scared that I won’t be able to breathe properly”). Overall, the ASI–3 possesses good reliability and validity (see Taylor et al., 2007). For example, non-clinical groups display significantly lower levels of anxiety sensitivity across subscales than clinical groups with generalized anxiety disorder, social anxiety disorder, or panic disorder (Taylor et al., 2007). As well, the pattern of scores by clinical group differ by ASI–3 subscale (e.g., physical concerns highest in panic disorder; social concerns highest in social anxiety disorder; Taylor et al., 2007). In the present study, Cronbach’s alpha was .94 for the total score and .88, .91, and .84 for the physical, cognitive, and social concerns subscales, respectively. Moreover, factorial validity has been shown for the ASI–3 in athletes and measurement invariance has been demonstrated between athletes and non-athletes (DeWolfe et al., 2022).

German Socio-Economic Panel Study (GSOEP) Big Five Inventory (BFI-S).

Participants completed an English translation of the GSOEP Big Five Inventory (BFI-S; Gerlitz & Schupp, 2005). The BFI-S is a short 15-item self-report measure of the Big Five personality traits (i.e., openness, conscientiousness, extraversion, agreeableness, and neuroticism) based on the 44-item Big Five Inventory *(BFI*; John et al., 1991; John & Srivastava, 1999). There are three items per subscale, each rated on a 7-point scale (1 = *strongly disagree*; 7 = *strongly agree*). For the present study, only the three items of the neuroticism subscale were used (e.g., “Gets nervous easily”). In the present study, Cronbach’s alpha for the neuroticism subscale was acceptable at .70. Previous research has established the test-retest reliability of the German version (18-month test-retest correlation = .74 for neuroticism subscale; Hahn et al., 2012). Studies on both German and English versions have established that this three-item neuroticism measure has strong

correlations with the full BFI neuroticism subscale (r = .89) and with the BFI neuroticism items that were not included in the short version (r = .70; Donnellan & Lucas, 2008). The German version of the BFI-S demonstrates appropriate structural validity (i.e., mean loading of items onto their subscale = .74 and mean loading onto other factors = .12). The neuroticism scale has appropriate convergent validity (i.e., average correlation = .50 between BFI-S neuroticism and neuroticism facets of the NEO Personality Inventory Revised [NEO-PI-R]; Costa & McCrae, 1992) and discriminant validity (i.e., absolute value of discriminant correlations between BFI-S neuroticism scale and NEO-PI-R personality facets ranging from 0.00 to -.36 and not exceeding any convergent correlation; Hahn et al., 2012).

Generalized Anxiety Disorder Dimensional Scale (GAD-D). The Generalized Anxiety Disorder Dimensional Scale (GAD-D) (Lebeau et al., 2012) is a 10-item self-report measure that assesses various symptoms of generalized anxiety disorder and associated characteristics including frequency of anxiety, worry, fear, physical symptoms (e.g., muscle tension), avoidance, safety behaviours, reassurance seeking, and coping. The measure asks respondents to report on the frequency of each symptom/characteristic (e.g., "felt anxious, worried or nervous") in the past 7 days on a 5-point scale (0 = *never*; 4 = *all of the time*). In the present study, Cronbach's alpha was .89, which is comparable to that found in a validation study (Cronbach's alpha = .92; Lebeau et al., 2012). Convergent and divergent validity of this scale is shown in that the correlation (r_s = .67) between this measure and the well-validated Generalized Anxiety Disorder - 7 (GAD-7; Spitzer et al., 2006) is significantly stronger than between this measure and validated measures of social anxiety (r_s = .48), panic (r_s = .43), and agoraphobia (r_s = .18). Scores are significantly higher in clinical samples compared to non-clinical samples. The test-

retest stability coefficient for this measure with an average of 11.8 days in-between measurements was adequate at .74 (Lebeau et al., 2012).

Mini Social Phobia Inventory. The Mini-Social Phobia Inventory (MINI-SPIN; Connor et al., 2001) was used to assess symptoms of social phobia. The MINI-SPIN is a 3-item self-report measure. Each item (e.g., "Fear of embarrassment causes me to avoid doing things or speaking to people") is rated on a 5-point severity scale (0 = *not at all*; 4 = *extremely*). In the present study, Cronbach's alpha was .82. The MINI-SPIN has shown good stability (12-week test-retest reliability, r = .70). Scores on the MINI-SPIN have been shown to be significantly different between clinical samples with a primary social anxiety disorder diagnosis and non-clinical samples (Seeley-Wait et al., 2009). Scores have also been shown to be significantly correlated with other measures of social anxiety establishing construct and convergent validity (i.e., Social Interaction Anxiety Scale; Social Phobia Scale; Mattick & Clarke, 1998). As well, scores are sensitive to change following CBT for social anxiety (Seeley-Wait et al., 2009).

Panic Attack Questionnaire-IV. The Panic Attack Questionnaire-IV (PAQ-IV; Norton et al., 2008) is a validated self-report measure of panic disorder symptoms. A single item from the PAQ-IV was included in the battery to assess frequency of past year panic attacks: "In the past year approximately how many panic attacks have you had?" Before answering, participants were provided with a definition of a panic attack. Response options were: 0, 1-2, 3-6, 6-10, and more than 10. This item has commonly been used to determine past year panic attack rates in prior research (e.g., Mathew et al., 2011; Norton et al., 2008).

Patient Health Questionnaire-9. The Patient Health Quesionnaire-9 (PHQ-9; Kroenke et al., 2001) is a widely used 9-item self-report measure for assessing depressive symptoms. Participants report on the frequency of various depressive symptoms (e.g., "Little interest or

pleasure in doing things") occurring over the past two weeks. Each item is rated on a 4-point frequency scale (0 = *not at all*; 3 = *nearly every day*). Cronbach's alpha for the PHQ-9 in the present study was .90. The PHQ-9 has excellent test-retest reliability (i.e., 2-day test-retest r = .84; Kroenke et al., 2001).Validity of this measure has been established in that scores are related to functional status as measured by the Medical Outcomes Study Short-Form General Health Survey, with the strongest association being as expected with the mental health scale (r = -.73; Stewart et al., 1988). Scores are also positively associated with health care utilization and interference in functioning (Kroenke et al., 2001).

Results

It was determined that the past year panic attack frequency variable on the PAQ-IV (Norton et al., 2008) was substantially zero inflated in that almost two-thirds of the sample reported experiencing zero panic attacks in the past year. Thus, it was decided to dichotomize this variable (any vs. no panic attacks in the past year) in all analyses. See Table 6.1 for intercorrelations, means, and standard deviations of all study variables. Mean global anxiety sensitivity scores of 16.2 (13.8) appear comparable to 16.7 (11.0) found in a sample of 954 students (Ebesutani et al., 2014) and mean subscale scores were all within 1.4 units (each subscale assessed using six items with response options from zero to four) between studies. All intercorrelations between study variables were significant (p<.05). Notably, anxiety sensitivity total scores and neuroticism scores shared about 25% common variance, and both anxiety sensitivity total and subscale scores and neuroticism were correlated with each of the outcome variables. Overall correlations between study variables ranged from r = .27 (PAQ-IV with PHQ-9) to r = .91 (ASI–3 Total with ASI–3 Cognitive Concerns). Regarding emotional symptoms, mean GAD-D scores were lower than previously found in undergraduates (M = 11.2, SD = 6.2;

Lebeau et al., 2012). MINI-SPIN scores were higher than non-clinical means (*M* = 1.8, *SD* = 1.6; Seeley-Wait et al., 2009) and the average score fell below the recommended cut-off score of six for identifying those with likely social anxiety disorder (Seeley-Wait et al., 2009). PHQ-9 scores were also higher than participants without a depressive disorder (*M* = 3.3, *SD* = 3.8; Kroenke et al., 2001) and the group average fell in the mild range of depression severity (Kroenke et al., 2001). More participants appeared to report experiencing a panic attack in the previous year versus previously found (22.1%; Norton et al., 2008). Mean BFI-S neuroticism scores were slightly lower than previously found in a German sample (*M* = 12.55, *SD* not reported; Hahn et al., 2012).

Before conducting planned regression analyses, it was determined that multivariate outliers were present in the data based on a Mahalanobis distance beyond a critical chi square value. An inspection of raw scores for these outliers suggested the scores were unlikely values and they were removed. This resulted in one outlier removed in the analyses examining anxiety sensitivity and neuroticism as predictors of emotional disorder symptoms, and three outliers removed in the analyses of anxiety sensitivity subscale scores predicting emotional disorder symptoms.

Multiple linear regression results (Table 6.2a) revealed that anxiety sensitivity total was a significant predictor of generalized anxiety, social anxiety, and depressive symptoms, above-and-beyond neuroticism. In all three cases, both anxiety sensitivity and neuroticism proved significant, independent predictors, but anxiety sensitivity accounted for more unique variance than neuroticism. For generalized anxiety and depressive symptoms, anxiety sensitivity predicted 24 times and 8.5 times the unique variance that neuroticism did, respectively. For social anxiety symptoms, anxiety sensitivity uniquely predicted somewhat more variance than neuroticism (1.1

times). When examining the predictive ability of anxiety sensitivity and neuroticism in predicting past year panic attacks via binary logistic regression, the Hosmer and Lemeshow test indicated sufficient model fit, $\chi 2$ (8) = 5.42, p = .71. Both anxiety sensitivity total scores and neuroticism significantly, independently, and positively predicted past year panic attack occurrence on the PAQ-IV (Table 6.3a). Odds of experiencing a panic attack rose 5% with each one-point increase in anxiety sensitivity and 12% with each one-point increase in neuroticism. As a supplementary analysis, logistic regressions for anxiety sensitivity and neuroticism predicting past year panic attacks were run separately to determine changes in model fit relative to the combined predictor model. Results indicated increases in Nagelkerke R^2 were greater when adding anxiety sensitivity to the model with neuroticism (Δ Nagelkerke R^2 = .78) than when adding neuroticism to the model with anxiety sensitivity (Δ Nagelkerke R^2 = .41).

When examining the predictive ability of anxiety sensitivity domains, we decided to not control for neuroticism given the purpose of these analyses was to identify the potential unique contributions of anxiety sensitivity domains themselves in predicting emotional disorder symptoms. This is an important first step in work with athletes that should proceed assessing the domains' unique predictive abilities above and beyond neuroticism in future work. Results indicated unique patterns of associations across emotional disorder symptom outcomes. Results (Table 6.2b) indicated that, of the anxiety sensitivity domains, only social concerns predicted unique variance in social anxiety symptoms; indeed, social concerns predicted at least 15 times more unique variance in social anxiety symptoms than each of the other two anxiety sensitivity domains. Both cognitive and social concerns predicted unique variance in generalized anxiety disorder symptoms as well as depressive symptoms. For generalized anxiety disorder symptoms, social concerns were the strongest predictor, predicting five percent of the unique variance in

generalized anxiety symptoms compared to three percent for cognitive concerns. For depressive symptoms, cognitive concerns were the strongest predictor, predicting twice as much variance in depressive symptoms as social concerns (four versus eight percent, respectively). For predicting past year panic attacks using anxiety sensitivity subscale scores, the Hosmer and Lemeshow test indicated sufficient model fit, $\chi 2$ (8) = 4.84, p = .78 in the binomial regression (Table 6.3b). However, none of the domain variables were significant unique predictors of past year panic controlling for the other two domain scores. Odds ratios indicated that a unit increase in cognitive concerns led to the greatest increase in odds of having a panic attack in the past year at 9%, compared to 5% for physical concerns and 7% for social concerns.

Discussion

Results of the present study largely supported the hypotheses. Consistent with the first hypothesis, anxiety sensitivity was significantly associated with emotional disorder symptoms of generalized anxiety, social anxiety, depression, and past year panic attacks in the athlete sample. As predicted in the second hypothesis, anxiety sensitivity was a significant predictor of each of these symptoms above-and-beyond neuroticism. In fact, anxiety sensitivity was a stronger predictor of emotional disorder symptoms than neuroticism, particularly in the cases of generalized anxiety, depressive, and panic symptoms. Furthermore, the results of the anxiety sensitivity domain analyses provided partial support for the third set of hypotheses. In line with our predictions, anxiety sensitivity social concerns were a significant unique predictor of social anxiety symptoms, and anxiety sensitivity cognitive concerns was a significant and unique predictor of both generalized anxiety symptoms and depressive symptoms. Contrary to our predictions, however, anxiety sensitivity cognitive concerns and physical concerns were not unique predictors of the presence of panic attacks in the past year, and anxiety sensitivity social

concerns was a significant additional predictor of both generalized anxiety and depressive symptoms.

Anxiety sensitivity serving as a significant predictor of a variety of emotional disorder symptoms is consistent with previous cross-sectional (Olatunji & Wolitzky-Taylor, 2009) and longitudinal research (Hovenkamp-Hermelink et al., 2019) conducted outside of the university athlete context. In the present study, anxiety sensitivity remained a significant predictor of emotional disorder symptoms and extended previous research by showing these effects hold above-and-beyond neuroticism and demonstrating their presence in an athletes-only sample. Despite a clear association between anxiety sensitivity and emotional disorder symptoms, there is research in general population samples suggesting that other variables (e.g., maladaptive emotion regulation and beliefs about emotions; Ouimet et al., 2016) may mediate this relationship. It is likely that these factors are also involved in the anxiety sensitivity-physical activity relation for athletes – a potential direction for future athlete-specific research.

Regarding the three subdomains of anxiety sensitivity, the results were generally consistent with what has been found in general samples. All domains were significantly correlated with symptoms of generalized anxiety, social anxiety, and depression as well as the occurrence of past year panic attacks. When examining unique contributions of anxiety sensitivity domains, anxiety sensitivity social concerns was the only domain to significantly predict unique variance in social anxiety symptoms. This replicates previous research (Allan, Capron, et al., 2014; Olthuis, Watt, & Stewart, 2014), although some research has shown cognitive concerns to also predict unique variance in social anxiety symptoms (Olthuis, Watt, & Stewart, 2014). Both anxiety sensitivity cognitive concerns and social concerns were unique predictors of generalized anxiety symptoms. This is consistent with previous research by Allan,

Capron, et al. (2014) examining worry, a key characteristic of generalized anxiety disorder (American Psychiatric Association, 2013). Although Olthuis, Watt, and Stewart (2014) did not find that any of the anxiety sensitivity domains predicted unique variance in worry, they suggested that their results warranted further exploration as they believed they were the first to examine the relation between ASI–3 scores and worry (as measured with the Penn State Worry Questionnaire; Meyer et al., 1990). Anxiety sensitivity cognitive concerns and social concerns were also unique predictors of depressive symptoms in our athlete sample. This is in line with previous research by Allan, Capron, et al. (2014), although Olthuis. Watt, and Stewart (2014) found only cognitive concerns to predict unique variance in depressive symptoms. The consistent links of anxiety sensitivity cognitive concerns with depression fit with the depression-distress amplification model, which suggests that anxiety sensitivity cognitive concerns can intensify the distress associated with various depressive symptoms (e.g., difficulty concentrating; Capron et al., 2012). Cox et al. (2001) suggested that rumination may mediate the relationship between anxiety sensitivity cognitive concerns and depressive symptoms – an idea that is likely to extend to student athletes and that could be tested in future in athlete-specific research.

With substantial previous research showing a strong association between anxiety sensitivity physical concerns and panic (Baek et al., 2019; Deacon & Abramowitz, 2006; Olthuis, Watt & Stewart, 2014), it was unexpected to find that anxiety sensitivity physical concerns were not a unique predictor of panic attacks in the past year in our athlete sample. According to Clark's (1986) cognitive approach to panic, catastrophizing on the meaning of bodily sensations, as is characteristic of those high in anxiety sensitivity physical concerns, can increase the severity of anxiety symptoms and lead to panic attacks. Perhaps athletes, who experience physical sensations in the absence of catastrophic consequence frequently via

vigorous-intensity exercise, learn that physical arousal sensations are safe. As a result, athletes would not catastrophize on the meaning of such physical sensations in the same way, thus, preventing the sensations from leading to a panic attack. At the same time, perhaps physical fitness, which is most closely linked to anxiety sensitivity physical concerns, serves as a buffer for these specific concerns leading to panic attacks by reducing the intensity of the sensations.

Overall, the present findings show that prior literature on the relation between anxiety sensitivity and emotional disorder symptoms in general populations extends to a student athlete sample. This was important to establish given the known inverse relationship between physical activity participation and anxiety sensitivity levels (DeWolfe et al., 2020), varied physiological characteristics (e.g., higher VO_2 max, lower resting heart rate, greater heart rate variability; Mendes et al., 2019; Pakkala et al., 2005) which may alter arousal experiences, and different sport-specific mental health factors (e.g., sport-related concussion; Rice et al., 2018). Since anxiety profiles between athletes and non-athletes are similar (Rice et al., 2019), one possible explanation for the similar pattern of results is that the utility of anxiety sensitivity in predicting emotional disorder symptoms may be more closely linked with anxiety-specific sensations than arousal-based sensations.

Limitations and Future Directions

The results of the present study should be considered in the context of the study limitations. The present study relied on cross sectional data and as a result, cause and effect cannot be inferred. Additionally, there are limitations with measurement. For example, using a single item to assess panic attacks may introduce measurement error and may have contributed to the null results regarding anxiety sensitivity domains predicting panic. Indeed, previous research has shown this item to overestimate the presence of panic attacks when compared to diagnostic

criteria (Mathew et al., 2011; Norton et al., 2008). Similarly, dichotomization of the panic measure (to manage the zero inflation in this outcome) reduced power relative to a continuous measure of panic frequency, again potentially affecting our ability to detect the predicted anxiety sensitivity domain associations for this outcome. Future research may benefit from using more comprehensive measures of panic disorder symptoms. The present study used a university student athlete sample. Future research would benefit from extending the findings of the present study by determining if anxiety sensitivity is associated with other mental health concerns such as substance abuse or posttraumatic stress in athletes given such links established in non-athlete samples (Allan et al., 2015; Naragon-Gainey, 2010; Paulus & Zvolensky, 2020). To overcome some of the limitations associated with self-report data, future research examining the relationship between anxiety sensitivity and athlete mental health would benefit from more comprehensive assessment of mental health concerns (e.g., structured interviews).

Clinical Implications

The findings of the present study are meaningful from a clinical perspective. The results show that anxiety sensitivity is strongly associated with several types of emotional disorder symptoms in athletes. This provides initial support for anxiety sensitivity as a transdiagnostic mental health risk factor in athletes, specifically. This means anxiety sensitivity may be a useful transdiagnostic treatment target for clinicians working with this population. In other words, clinicians may wish to target anxiety sensitivity when working with athletes who experience symptoms across emotional disorders (e.g., anxiety and depression) or have comorbid diagnoses. Alternatively, clinicians with limited resources may wish to implement group-based anxiety sensitivity treatments that would be applicable to individuals experiencing a variety of different disorders/symptoms. Fortunately, evidence-based treatments for anxiety sensitivity exist and can

even be delivered via telehealth (e.g., Olthuis, Watt, Mackinnon et al., 2014). The present results also suggest some specificity regarding anxiety sensitivity domains. When providing anxiety sensitivity treatment for athletes, it may be valuable to specifically target social concerns and cognitive concerns over physical concerns given the former's unique associations with anxiety and depressive symptoms.

Table 6.1. *Bivariate Correlations for Study Variables*

	1	2	3	4	5	6	7	8	9	*M*	*SD*
1. AS Total	---									16.16	13.83
2. AS Physical Concerns	.860**	---								4.15	4.87
3. AS Cognitive Concerns	.914**	.700**	---							4.73	5.42
4. AS Social Concerns	.878**	.605**	.713**	---						7.27	5.33
5. Mini SPIN	.559**	.365**	.498**	.609**	---					3.39	2.75
6. GAD-D	.635**	.489**	.597**	.591**	.563**	---				7.27	6.09
7. PHQ-9	.582**	.377**	.603**	.552**	.549**	.778**	---			6.11	5.66
8. PAQ-IV	.421**	.344**	.395**	.375**	.330**	.372**	.271**	---		38.3%[a]	---
9. BFI-S Neuroticism	.513**	.361**	.465**	.508**	.510**	.426**	.402**	.358**	---	10.63	4.44

*p<.05, **p<.01. AS = Anxiety sensitivity on the Anxiety Sensitivity Index – 3(ASI–3; Taylor et al., 2007); Mini SPIN = Mini Social Phobia Inventory (Connor et al., 2001); GAD-D= Generalized Anxiety Disorder Dimensional Scale (Lebeau et al., 2012); PHQ-9 = Patient Health Questionnaire - 9 (Kroenke et al., 2001); PAQ-IV = Panic Attack Questionnaire (Norton et al., 2008); BFI-S Neuroticism = GSOEP Big Five Inventory Neuroticism Subscale (Gerlitz & Schupp, 2005). [a]Percentage of participants who reported that they had experienced one or more panic attacks in the past year.

Table 6.2. *Regression of Anxiety Sensitivity Total Scores and Neuroticism Predicting Continuous Emotional Disorder Symptoms with a. Anxiety Sensitivity Total and Neuroticism and b. Anxiety Sensitivity Subscale Scores*

Model	Outcome	Predictor	B	SE	β	*t*	*p*	Sr^2	R^2
a. Anxiety Sensitivity Total									
	Mini SPIN								.376
		Anxiety Sensitivity**	.077	.012	.385	6.339	<.001	.11	
		Neuroticism**	.192	.037	.313	5.152	<.001	.10	
	GAD-D								.405
		Anxiety Sensitivity**	.225	.026	.521	8.782	<.001	.24	
		Neuroticism*	.238	.078	.181	3.050	.003	.01	
	PHQ-9								.344
		Anxiety Sensitivity**	.202	.026	.490	7.859	<.001	.17	
		Neuroticism*	.194	.079	.154	2.470	.014	.02	
b. Anxiety Sensitivity Domains									
									.371
	Mini SPIN	Physical	-.041	.043	-.070	-.945	.346	<.01	
		Cognitive	.064	.044	.124	1.495	.146	.01	
		Social**	.287	.038	.558	7.493	<.001	.15	
									.404
	GAD-D	Physical	.091	.094	.070	.970	.333	<.01	
		Cognitive**	.343	.095	.299	3.609	<.001	.03	
		Social**	.382	.083	.333	4.589	<.001	.05	
									.378
	PHQ-9	Physical	-.159	.088	-.134	-1.812	.071	.01	
		Cognitive**	.486	.089	.463	5.471	<.001	.08	
		Social**	.310	.078	.295	3.979	<.001	.04	

Mini SPIN = Mini Social Phobia Inventory; GAD-D = Generalized Anxiety Disorder Dimensional Scale (GAD-D); PHQ-9 = Patient Health Questionnaire - 9; Physical = Anxiety Sensitivity Physical Concerns; Cognitive = Anxiety Sensitivity Cognitive Concerns; Social = Anxiety Sensitivity Social Concerns.

Table 6.3. *Binomial Regression Results Predicting Occurrence of Panic Attacks in the Past Year with a. Anxiety Sensitivity Total and Neuroticism and b. Anxiety Sensitivity Subscale Scores*

Model	Predictor	B	SE	Wald	*df*	*p*	Exp(B) [95%CI]	Nagelkerke R^2
a. Anxiety Sensitivity Total								.26
	Anxiety sensitivity	.05	.01	15.10	1	<.01	1.05 [1.03, 1.08]	
	Neuroticism	.12	.04	8.48	1	<.01	1.12 [1.04, 1.22]	
	Constant	-2.64	.45	35.04	1	<.01	.07	
b. Anxiety Sensitivity Domains								.22
	Physical concerns	.05	.04	1.06	1	.30	1.05 [.96, 1.14]	
	Cognitive concerns	.08	.05	3.47	1	.06	1.09 [1.00, 1.90	
	Social concerns	.07	.04	3.30	1	.07	1.07 [.99, 1.16]	
	Constant	-1.64	.27	37.32	1	<.01	.20	

CHAPTER 7. GENERAL DISCUSSION

Summary

The purpose of this dissertation was to advance our understanding of the anxiety sensitivity–physical activity relationship. Specific aims were to: a) provide the best available estimate of the strength of the anxiety sensitivity–physical activity relationship and explore potential moderators of the relationship using meta-analysis (Study 1); b) test the mediational role of anxiety sensitivity in explaining the effect of gender on physical activity levels (Study 2); and c) examine whether anxiety sensitivity serves as a transdiagnostic risk factor for emotional disorder symptoms in a highly physically active sample of varsity athletes, as has been previously established in the general population (Study 3). This dissertation met these aims across three studies that demonstrated the interconnectedness of anxiety sensitivity and physical activity in three unique ways. These advances included revealing a small and significant relation between anxiety sensitivity and physical activity through a meta-analysis (Study 1), establishing that gender differences in anxiety sensitivity contribute to gender differences in physical activity (Study 2), and showing that anxiety sensitivity predicts a variety of emotional disorder symptoms even in a highly physically active sample of varsity athletes (Study 3).

The primary aim of Study 1 was to provide the best available estimate of the magnitude of the anxiety sensitivity–physical activity relationship. Study 1 accomplished this aim using meta-analysis, capturing data from 43 studies and 10,303 individuals. The results revealed a small but significant inverse relationship between anxiety sensitivity and physical activity. This was an important contribution that provided clarity to the inconsistent results across the existing literature (e.g., significant negative relation in DeWolfe et al. (2020), Hearon & Harrison, (2021); and Sabourin et al., (2011) versus a non-significant relation in DeBoer et al. (2012) and

Moshier et al. (2016)). In the future, researchers are encouraged to frame this relationship according to these meta-analytic results.

A secondary aim of Study 1 was to assess potential moderators of the anxiety sensitivity–physical activity relationship. The results revealed that the relationship was stable across several assessed moderators including location of study, study quality, publication status, forms of measurement, and participant characteristics including sex, race, age, physical health status, and body mass index. Although individual studies have shown factors such as sex (McWilliams & Asmundson, 2001) and body mass index (Hearon et al., 2014) moderate the anxiety sensitivity–physical activity relationship, these meta-analytic results question the robustness of those prior moderation findings.

Study 1 results indicated that the inverse anxiety sensitivity–physical activity relationship is stronger with increasing physical activity intensity. Although physical activity intensity was not assessed as a formal moderator but rather by comparing the magnitude and significance of the relation across physical activity intensity categories, the magnitude of the effect increased with increasing physical activity intensity and the relationship was only significant at moderate and vigorous intensities. The role of physical activity intensity in the anxiety sensitivity–physical activity relationship appears to be robust as it has been found in several studies (e.g., Galbraith et al., 2022; Moshier et al., 2013). This finding fits with anxiety sensitivity theory (Otto et al., 2016; Reiss, 1991; Reiss & McNally, 1985; Stewart & Watt, 2008) as higher intensity physical activity elicits stronger arousal sensations, potentially creating greater motivation for physical activity avoidance among individuals with elevated anxiety sensitivity. Additional factors may also contribute to the role of physical activity intensity in the anxiety sensitivity–physical activity relationship. For example, low-intensity physical activity (e.g., walking) is typically required for

day-to-day activities while high-intensity physical activity (e.g., running) is not. This may make it more difficult for individuals high in anxiety sensitivity to avoid lower-intensity physical activity and/or create greater opportunity for exposure to low-intensity-related arousal sensations. Thus, the stronger relationship between anxiety sensitivity and physical activity at higher intensities may be due in part to higher-intensity physical activities being more of a voluntary pursuit than lower-intensity physical activity.

In Study 1, the significance of the anxiety sensitivity–physical activity relationship also varied across anxiety sensitivity domains. Although not assessed as a formal moderator, but by comparing the magnitude and significance of the relation across anxiety sensitivity domains, physical concerns and cognitive concerns showed a significant and inverse relationship with physical activity, but social concerns did not. It may be that social concerns can be more easily avoided when engaging in physical activity than physical or cognitive concerns. For example, if an individual engages in physical activity, it is likely that they will experience physical sensations that parallel those when anxious (e.g., increased heart rate) and they may experience cognitive sensations associated with anxiety (e.g., mind going blank) as well. However, individuals can engage in physical activity without worrying about potential catastrophic social consequences (e.g., when engaging in physical activity alone).

Finally, the results of Study 1 indicated that mental health status plays a role in the relationship between anxiety sensitivity and physical activity. Unexpectedly, the relationship appears to be stronger for general population samples compared to clinical mental health samples. The heterogeneity of clinical samples may contribute to this finding, although there were insufficient studies to compare specific clinical populations. Many of the clinical samples included in the meta-analysis were made up of individuals with anxiety disorders. Anxiety

sensitivity may motivate some with clinical levels of anxiety to engage in exercise because of its anxiolytic effects. In other words, they may engage in physical activity despite feared arousal sensations because it reduces the anxiety-specific arousal that may be even more feared. Eating disorder samples were also included in the meta-analysis. For individuals with eating disorders, anxiety sensitivity may also be associated with increased physical activity as exercising after a meal serve as a compensatory behaviour that reduces the anxiety associated with eating. Range restriction in the clinical samples may also be a contributor, given anxiety sensitivity tends to be higher in clinical populations and may have limited range due to ceiling effects compared to general population samples with broader levels of anxiety sensitivity.

With clear support of an inverse relation between anxiety sensitivity and physical activity from Study 1, Study 2 sought to determine if gender differences in anxiety sensitivity contributed to gender differences in physical activity levels. Although Study 1 found that sex did not moderate the relation between anxiety sensitivity and physical activity, it did not assess the potential mediating role of anxiety sensitivity in gender differences in physical activity. Thus, in Study 2, we examined if gender differences in anxiety sensitivity levels, with women tending to have higher levels than men (Stewart et al., 1997), help to explain why women tend to engage in lower levels of physical activity (Trost et al., 2002), given anxiety sensitivity is a barrier to physical activity. This question was explored in a sample of 802 university students who completed measures of demographics, anxiety sensitivity, and lifestyle factors (including physical activity). The mediational model in Study 2 provided evidence of a significant indirect effect. In other words, the results showed that anxiety sensitivity is one mechanism through which women come to engage in lower levels of physical activity than men. Unsurprisingly, anxiety sensitivity was shown to be a partial mediator, explaining only a part of the relationship

between gender and physical activity involvement. Specifically, anxiety sensitivity was shown to account for 8.4% of gender differences in physical activity levels. This indicates that other unexamined variables in addition to anxiety sensitivity are also involved in mediating (explaining) this relationship. Additional aims of Study 2 were to replicate previous findings showing that: a) anxiety sensitivity is elevated in women compared to men; b) women engage in lower levels of physical activity than men, and c) anxiety sensitivity is associated with lower levels of physical activity. The results of Study 2 replicated these previous results as predicted. It is hoped that these results help to bring light to the concerning gender gap in physical activity levels and support efforts to reduce this gap (e.g., through targeting anxiety sensitivity reduction in women to help increase their physical activity participation).

Taken together, the results of Study 1 and Study 2 highlight that anxiety sensitivity is inversely associated with physical activity levels. This finding contributes to the broader literature examining the role of psychological factors in physical activity participation. Existing studies reveal a complex association between psychological factors and physical activity further complicated by the plethora of psychological factors that have been examined (Cortis et al., 2017). As a result, researchers have been called to reach consensus and have clear definitions of the psychological constructs involved in physical activity behaviour (Cortis et al., 2017). The fact that anxiety sensitivity is a clearly defined construct, commonly assessed with only a few validated measures, adds value to the findings of Study 1 and Study 2.

After examining relationships between anxiety sensitivity and physical activity levels in Study 1 and Study 2, Study 3 was designed to assess the transdiagnostic utility of anxiety sensitivity as it relates to physical activity. Specifically, Study 3 examined the associations between anxiety sensitivity and emotional disorder symptoms in a highly physically active

sample. This aim aligns with the identified need for research on transdiagnostic constructs in athlete samples (Ekelund et al., 2022). Specifically, the primary aim of Study 3 was to determine if anxiety sensitivity predicts emotional disorder symptoms in a sample of varsity athletes, in the same way that it has been shown to do in general population samples. Varsity athletes have lower levels of anxiety sensitivity compared to their non-physically active university student counterparts (DeWolfe et al., 2022). With their lower levels of anxiety sensitivity, it is possible that anxiety sensitivity loses its ability to predict emotional disorder symptoms (e.g., due to floor effects). Study 3 measured anxiety sensitivity, neurotic personality, and emotional disorder symptoms (i.e., social anxiety, generalized anxiety, depression, past year panic attacks) among varsity athletes from a single university. Results revealed that anxiety sensitivity predicted each of the emotional disorder symptoms assessed. Additionally, anxiety sensitivity predicted emotional disorder symptoms above and beyond neuroticism and generally accounted for more unique variance in emotional disorder symptoms than neuroticism. This is consistent with previous research showing anxiety sensitivity predicts panic attacks in another highly physically active sample, namely military personnel, despite their lower levels of anxiety sensitivity relative to the general population (Schmidt et al., 1997; Schmidt et al., 1999). The results of Study 3 add to the literature by supporting the transdiagnostic utility of anxiety sensitivity in varsity athletes, a population in need of additional mental health research and support (Ekelund et al., 2022).

A secondary aim of Study 3 was to examine unique relationships between anxiety sensitivity domains and emotional disorder symptoms in varsity athletes. Consistent with previous research (Allan, Capron, et al., 2014; Olthuis, Watt & Stewart, 2014), the results of Study 3 revealed unique patterns of associations between anxiety sensitivity domains and emotional disorder symptoms. Specifically, cognitive and social concerns predicted unique

variance in generalized anxiety symptoms and depression symptoms, while only social concerns uniquely predicted social anxiety symptoms. Unexpectedly, however, physical concerns were not a unique predictor of any emotional disorder symptoms assessed. Theoretically, physical activity is most closely associated with physical concerns due to the physical sensations that occur during physical activity. The lack of unique variance predicted by physical concerns may be due to low levels of physical concerns in athletes creating a floor effect. Overall, Study 3 results provide further support for the specificity of anxiety sensitivity domains in predicting mental health outcomes (Naragon-Gainey, 2010) and extended these findings to an athlete sample. This was an important extension given athletes' increased physical activity levels which are known to impact both anxiety sensitivity and mental health (e.g., Broman-Fulks et al., 2018), their increased physical fitness which may impact the experience of arousal (Mendes et al., 2019; Pakkala et al., 2005), and sport-specific mental health factors (Rice et al., 2018).

It is important to mention the findings of this dissertation as they relate to sex and/or gender with sex referring to biological characteristics and gender referring to socially constructed roles/identities. As previously mentioned, previous research has been unclear and inconsistent when referring to these terms and clarity is required moving forward. In Study 1, we found that sex did not moderate the relation between anxiety sensitivity and physical activity across the existing literature. In Study 2, we found that anxiety sensitivity mediated gender differences in physical activity levels. Taken together, these findings suggest that although the magnitude of the anxiety sensitivity–physical activity relation is consistent across sex, the elevated levels of anxiety sensitivity in women account for some of the gender differences in physical activity levels. Thus, women appear to be at risk for lower physical activity participation due to elevated anxiety sensitivity levels, rather than there being differences in the magnitude of the inverse

relation of anxiety sensitivity to physical activity in females vs. males. In Study 3, we found anxiety sensitivity to predict a variety of emotional disorder symptoms in athletes. Important considerations regarding sex and physical activity in Study 3 are that the sample was relatively sex balanced and all participants in the varsity athlete group would have been involved in high levels of physical activity. With both males and females having elevated levels of physical activity, this sample differed in a meaningful way from those in Study 1 and Study 2. Further examination of the potential moderating role of sex and/or gender in anxiety sensitivity's prediction of emotional disorder symptoms in athletes is warranted.

Strengths and Limitations

There are several strengths and limitations of this dissertation to highlight. In Study 1 the methodologies and analyses used followed gold standard PRISMA guidelines (Page et al., 2021). Methodological strengths include pre-registration, the inclusion of several databases in the search, the use of broad search terms, multiple screeners to ensure reliability of extraction and coding, and a validated measure of study quality. Strengths of the data analysis include assessing and correcting for potential publication bias and testing a wide variety of potential moderators. Taken together, these strengths add to the confidence in the estimate of the overall effect. The data analytic approach was also a strength of Study 2. By using bias-corrected bootstrapped confidence intervals, the results are robust against less-than-ideal data patterns (e.g., non-normal distribution). As well, Study 2 tested a parsimonious model to minimize the number of statistical tests used and to clearly display the results. Strengths of Study 3 included having athletes across all sports at the university, gender, and year of study, as this allows better generalization of results to other university athlete populations. As well, the effects of anxiety sensitivity were examined while controlling for the related construct of neuroticism, providing further support of

the unique value of anxiety sensitivity in predicting emotional disorder symptoms in varsity athletes.

An overall strength of the studies included in this dissertation is their reliance on a well-validated measure of anxiety sensitivity, the Anxiety Sensitivity Index – 3(Taylor et al., 2007). This measure was best suited for the aims of the dissertation given its sound psychometric properties. Measurement invariance has been shown for the ASI–3 between genders (Ebesutani et al., 2014), relevant for Study 2, and between athletes and non-athletes (DeWolfe et al., 2022), relevant for Study 3. The ASI–3 also outperforms other measures of anxiety sensitivity when measuring anxiety sensitivity domains (Taylor et al., 2007), which was important for the subscale analyses in Study 3. The use of such a commonly used measure of anxiety sensitivity also facilitates comparisons of the present findings with other studies in the literature.

Another strength of the studies across this dissertation is their large sample sizes. In meta-analytic Study 1, there were over 10,000 participants captured to assess the anxiety sensitivity–physical activity relationship. In Study 2, a sample of 802 participants was used to assess the mediating role of anxiety sensitivity in the relationship between gender and physical activity. Study 3 assessed the association between anxiety sensitivity and emotional disorders among 244 student athletes, capturing most of the athletes at the university where data collection occurred. A lack of adequate power is too common a concern in psychological research (Maxwell, 2004) and all studies in this dissertation were adequately powered.

As with all research, the studies in this dissertation are not without limitation. One limitation is the reliance on self-report measures. Self-report data relies on accurate reporting from participants, which may be impacted by various psychological processes including social desirability effects (Adams et al., 2005). Fortunately, research shows that social desirability

effects on physical activity self-report measures are minimal (Motl et al., 2005) thereby reducing this concern. Nevertheless, some of the self-report measures used in the studies in this dissertation do have some drawbacks. First, the self-report measure used in Study 2 to assess physical activity was author-compiled; the study would have benefited from a more well-validated measure of physical activity such as the International Physical Activity Questionnaire - Short Form (Craig et al., 2003; Lee et al., 2011). Second, participants' responses to the self-report assessment of emotional disorder symptoms in Study 3 may have been influenced by the strong mental health stigma in the sport environment, which may discourage honest disclosure of mental health symptoms among athletes (Rao & Hong, 2020). Third, there is research indicating that the measure used to assess past year panic attacks in Study 3 (i.e., the PAQ-IV; Norton et al., 2008) often provides an overestimate of panic attacks when compared to diagnostic criteria; results using this measure should thus be interpreted cautiously (Mathew et al., 2011; Norton et al., 2008). Thus, the failure of the expected relation between anxiety sensitivity physical concerns and panic attacks to emerge in Study 3 might have been secondary to measurement issues in the assessment of panic. Forth, a limitation is the lack of using objective measures of physical activity. Objective measures (e.g., accelerometer) allow physical activity to be assessed directly and without recall bias. As shown in Study 1, most studies on anxiety sensitivity and physical activity rely on questionnaire-based measurement, so more research using objective measures are needed. Fortunately, results of Study 1 show that the anxiety sensitivity–physical activity relationship is not moderated by physical activity measure type (i.e., objective measure versus questionnaire).

Another limitation of this dissertation is the reliance on cross-sectional data across studies. Cross-sectional studies, although a valuable first step in research, need to be interpreted

with caution. One caution that needs to be recognized is that such data cannot be used to make causal or temporal inferences. In Study 1, this means that we cannot infer that anxiety sensitivity causes lower levels of physical activity or that lower levels of physical activity cause elevated anxiety sensitivity, or that one even precedes the other. In Study 2, this means that we cannot firmly conclude that gender differences in anxiety sensitivity cause gender differences in physical activity levels, or that one precedes the other. In Study 3, this means that we cannot firmly conclude that anxiety sensitivity causes emotional disorder symptoms or that emotional disorder symptoms cause anxiety sensitivity, or that one even precedes the other. This leaves the door open for longitudinal and experimental research to explore these potential temporal and causal relationships.

Future Directions

Following the novel insights gained into the relations of anxiety sensitivity and physical activity from this dissertation, there remain promising and exciting directions for future research to explore. For example, despite theory suggesting catastrophizing on the meaning of arousal sensations can explain why individuals high in anxiety sensitivity engage in lower levels of physical activity (i.e., avoidance due to fear resulting from catastrophizing on the meaning of their anxiety-related sensations that occur during physical activity such as shortness of breath), the thoughts individuals with anxiety sensitivity have while engaging in physical activity remain unknown. Previous research has shown that anxiety sensitivity is associated with increased fear during exercise (Smits et al., 2010), yet it remains to be examined if this is in fact because they catastrophize on the meaning of arousal sensations in the moment. This warrants an investigation into the thought content of individuals with elevated anxiety sensitivity during physical activity. Such a study was initially planned to be a major part of this dissertation. The proposed study

involved having individuals complete an aerobic exercise task while verbalizing their thoughts aloud. This think-aloud approach has been used to capture thoughts during exercise tasks in other studies (e.g., Samson et al., 2017). The study protocol was developed, ethics approval was obtained, volunteers were trained in data collection, and the equipment needed was obtained and set up. Unfortunately, data collection was set to begin the week that the COVID-19 pandemic shut down the university to in-person research (not to mention the disruptions to the rest of the world!). As such, the study was abandoned to permit timely completion of the dissertation. Uncovering the thoughts of high anxiety sensitive individuals during exercise via empirical study remains a promising avenue to explore within anxiety sensitivity and physical activity research in the future.

Another gap in the existing literature on anxiety sensitivity and physical activity is a lack of research using longitudinal designs. The anxiety sensitivity–physical activity relationship appears to be bidirectional, as individuals with elevated anxiety sensitivity engage in lower levels of physical activity prospectively (Moshier et al., 2016) and exercise significantly reduces anxiety sensitivity (Broman-Fulks et al., 2004; Smits, Berry, Rosenfield, et al., 2008). Although the results of the Study 1 meta-analysis established a cross-sectional inverse relationship between anxiety sensitivity and physical activity, additional longitudinal research is needed to further explore the apparent bidirectionality. For example, future longitudinal investigations could explore anxiety sensitivity and sport participation. Previous research has shown that athletes have significancy lower levels of anxiety sensitivity than non-athletes (DeWolfe et al., 2022). However, it remains to be determined if the physical activity that athletes engage in contributes to their lower levels of anxiety sensitivity, and/or if there is self-selection process where individuals high in anxiety sensitivity do not pursue sport participation. Longitudinal research

would also serve to examine the stability of the anxiety sensitivity–physical activity relationship over time. Although physical activity levels at a young age tend to continue through the lifespan (Friedman et al., 2008) and anxiety sensitivity has been shown to have high stability over a two-year period (Hovenkamp-Hermelink et al., 2019), the stability of this relationship over time remains unknown. The results of Study 1 showed that age did not moderate the anxiety sensitivity–physical activity relationship; however, this does not rule out within-person changes over time.

There is also a need for more research examining the efficacy of targeting anxiety sensitivity to increase physical activity behaviour. The results of Study 1 and Study 2 suggest that anxiety sensitivity may be a barrier to physical activity participation. Research shows that anxiety sensitivity is a malleable treatment target and can be reduced with intervention, including brief intervention (Fitzgerald et al., 2021). Thus, anxiety sensitivity may be targeted to increase physical activity. This may be particularly beneficial for individuals experiencing mental health symptoms as these individuals tend to experience higher levels of anxiety sensitivity (Naragon-Gainey, 2010; Olatunji & Wolitzky-Taylor, 2009) and lower levels of physical activity (Goodwin, 2003). Such interventions may also be particularly useful for women given Study 2's results indicating that higher levels of anxiety sensitivity in women help to explain their lower levels of physical activity compared to men. In one study that attempted to examine the impact of reducing anxiety sensitivity on physical activity levels, the intervention did not significantly reduce anxiety sensitivity over time compared to the control group, despite the authors using an approach previously shown to be effective (Broman-Fulks et al., 2004; Broman-Fulks & Storey, 2008). This limits the ability to draw conclusions on the impact of reducing anxiety sensitivity on physical activity involvement (Lanoye et al., 2022). Nonetheless, in a mixed-methods study of

women who completed an 8-week learn to run program, quantitative results showed that the program significantly reduced anxiety sensitivity. In the same study, six out of seven women who completed interviews reported running more often and credited the program for this change (Olthuis et al., 2020). Additional quantitative results are needed to further understand if indeed anxiety sensitivity reductions can lead to increases in physical activity behaviour and whether such changes are sustained over time. If indeed anxiety sensitivity interventions can help physical activity promotion efforts, research could determine if this subsequently reduces mental health symptoms or risk for the emergence of mental health disorder. If mental health risk is reduced, research could also assess the individual contributions of anxiety sensitivity reductions and physical activity increases to this effect.

Furthermore, additional work is needed to better understand the role of mental illness in the anxiety sensitivity–physical activity relationship. In Study 1, results unexpectedly suggested that the strength of this relationship may be weaker in clinical populations compared to general populations. Perhaps in some cases, individuals with elevated anxiety sensitivity may not be as fearful of physical activity-induced arousal sensations because they can clearly identify that the cause is not anxiety. Some individuals high in anxiety sensitivity may only be fearful of arousal-based sensations specific to anxiety. Alternatively, some individuals high in anxiety sensitivity may engage in increased levels of physical activity to reduce experiencing their feared anxiety. Finally, it is possible that having a restricted range of anxiety sensitivity and/or physical activity scores weakened the association due to minimized variability. This might be particularly likely in clinical samples where anxiety sensitivity scores are higher on average (Naragon-Gainey, 2010; Olatunji & Wolitzky-Taylor, 2009) and physical activity levels are lower on average (e.g., Goodwin, 2003) than in the general population.

Another important avenue for future research to explore is the unique impact anxiety sensitivity has on physical activity behaviour. Indeed, there are several factors related to anxiety sensitivity that may also be contributing to lower levels of physical activity in individuals with elevated anxiety sensitivity. Interestingly, research has shown exercise exerts its effect on anxiety sensitivity rather than on intolerance of uncertainty (i.e., a tendency to view the possibility of negative events occurring as unacceptable regardless of probability; Dugas et al., 2001) or distress tolerance (i.e., perceived and/or behavioural ability to tolerate internal experiences associated with stressors and unpleasant emotional states; Zvolensky et al., 2010), two related transdiagnostic constructs (LeBouthillier & Asmundson, 2015). There remain many avenues for future research to examine factors associated with attention, fear, and tolerance of distress and arousal sensations. Regarding attention, the effect of body vigilance (i.e., increased attention towards bodily sensations) may contribute to the effect of anxiety sensitivity on physical activity. Anxiety sensitivity and body vigilance are related, and both are viewed as central to the development of panic (Olatunji et al., 2007). Perhaps body vigilance moderates the anxiety sensitivity–physical activity relation where individuals high in both anxiety sensitivity and body vigilance are more prone to avoid physical activity due to increased awareness and fear of arousal sensations. This may be particularly true for low-intensity physical activity, where changes in arousal are less pronounced and thus, may be more likely to become a focus among those with increased body vigilance. Additionally, interoceptive sensitivity (i.e., accuracy of detecting internal sensations) is associated with anxiety sensitivity and may also moderate the relation between anxiety sensitivity and physical activity in a similar way as proposed earlier for body vigilance (Domschke et al., 2010).

Regarding fear, more research is needed to identify the role, if any, fear plays in the anxiety sqensitivity–physical activity relation. If fear is involved, the contributions of cognitive (e.g., catastrophizing) and affective (i.e., fear of bodily sensations) mechanisms warrant investigation. Indeed, both components of fear have been proposed as part of "fear of fear", a construct similar to anxiety sensitivity (Chambless, 1988). As well, the specific nature of this fear remains unknown and future research is needed to examine the specificity or generality of the internal stimuli that are feared (e.g., anxious emotions, arousal, exertion, interoceptive experience). Perhaps fear is not involved and an intolerance of anxiety and/or related sensations drives this effect. Individuals may simply feel uncomfortable or have a low tolerance for anxiety-related sensations with or without these sensations being feared. An intolerance of arousal, with or without fear, may be sufficient to motivate physical activity avoidance. This intolerance may involve intolerance of anxiety, arousal, physical activity specific exertion, or broad interoceptive experience.

Finally, there are unique avenues to explore further when it comes to anxiety sensitivity and athlete mental health. Study 3 showed that anxiety sensitivity in athletes is associated with symptoms of generalized anxiety, social anxiety, depression, and panic attacks. In doing so, it provided needed initial support for a transdiagnostic mental health risk factor in athletes – anxiety sensitivity – and showed that anxiety sensitivity maintains its transdiagnostic utility in a sample with higher levels of physical activity. Future research examining the role of factors such as physical fitness, concussion history, and performance anxiety in the relationship between anxiety sensitivity and athlete mental health is a welcomed next step.

Research has shown that exercise reduces anxiety sensitivity in a stand-alone intervention (Broman-Fulks et al., 2004) and in combination with other cognitive-behavioural techniques

(e.g., cognitive restructuring; Smits, Berry, Rosenfield et al., 2008). However, research is needed to determine if such interventions are effective in reducing anxiety sensitivity and associated mental health concerns in athletes. Adjustments to typical anxiety sensitivity treatments, which often include physical activity as interoceptive exposure, may be needed for athletes, as they are already engaging in higher levels of physical activity. A few possible alterations for athlete populations may involve adjustments to interoceptive exposure techniques rather than using physical activity (e.g., spinning, straw breathing; Boswell et al., 2013), or placing a greater emphasis on cognitive techniques (e.g., cognitive restructuring).

Given that varsity athletes in Study 3 had a mean ASI–3 (Taylor et al., 2007) score of 16.2 (*SD* = 13.8), which appears to be comparable to other student samples (e.g., 16.7 [*SD* = 11.0] in a sample of 954 students in Ebesutani et al., 2014), future research is also needed to confirm if athletes' anxiety sensitivity levels are actually lower than non-athletes, as prior research has suggested (DeWolfe et al., 2022). Furthermore, if anxiety sensitivity levels in athletes are comparable to non-athletes, it remains to be determined what may be maintaining anxiety sensitivity levels in our athlete population despite their elevated physical activity. Future research using qualitative designs to study athletes with elevated anxiety sensitivity may provide useful insight into how an athlete can engage in high levels of physical activity and yet maintain a high level of anxiety sensitivity. It may be that such athletes fear anxiety-related sensations that occur outside of the context of physical activity (e.g., anxiety-related sensations experienced before a presentation) but not within sport. Alternatively, athletes may engage in safety behaviours in the context of sport (e.g., not exerting themselves as much as they could) which serve as a subtle form of avoidance, thereby maintaining their elevated fear of arousal sensations (Blakey & Abramowitz, 2016).

Theoretical Implications

The results of this research are aligned with existing theoretical perspectives. First, these results align with the expectancy model of fear (Reiss & McNally, 1985; Reiss, 1991). The expectancy model of fear suggests that avoidance is the result of a combination of expecting something to occur and the interpretation of the consequence(s) from the event occurring. In the case of anxiety sensitivity and physical activity, this theory would suggest that individuals with elevated anxiety sensitivity would engage in lower levels of physical activity because physical activity gives rise to feared anxiety-related sensations like racing heartrate, shortness of breath, and sweating. The findings in Study 1 align with this theory in that the inverse anxiety sensitivity–physical activity relationship becomes stronger with increasing exercise intensity. Increasing intensity of exercise is likely associated with increased expectancy of experiencing an increased heart rate. Logically, one may or may not expect shortness of breath, sweating, or an increase in heart rate from low-intensity physical activity. However, when engaging in vigorous-intensity physical activity these sensations are almost guaranteed. Thus, when expectancy of an experience (i.e., arousal sensations during vigorous-intensity physical activity) and sensitivity (i.e., anxiety sensitivity) are high, avoidance occurs.

Theory explaining the relation between anxiety sensitivity and physical activity is also presented by Otto et al. (2016). They developed a model highlighting the theorized role of anxiety sensitivity in a variety of health-related behaviours, including physical activity. In their model, factors such as stress and mood disturbance contribute to negative emotional experiences. Elevated anxiety sensitivity interacts with these emotional experiences to amplify distress and subsequently increase motives to avoid these negative experiences. These motives then impact engagement in health behaviours. Specifically, they increase negative health behaviours that

provide short-term relief of negative emotional experiences (e.g., substance use) and decrease positive health behaviours that provide short term discomfort or distress (e.g., exercise). In the case of exercise, the model suggests that individuals high in anxiety sensitivity would have difficulty increasing their physical activity levels, as that exposes them to increased distress which they are trying to avoid. The results of Study 1 and 2 align with this model in that individuals with elevated anxiety sensitivity engaged in less physical activity. Although not assessed in Study 3, anxiety sensitivity may lead to avoidance of exercise for athletes in the form of missing practices, workouts, or competitions.

The inverse relationship between anxiety sensitivity and physical activity highlighted in this dissertation also supports research showing that physical activity can reduce anxiety sensitivity (Jacquart et al., 2019). Theoretically, physical activity reduces anxiety sensitivity by serving as a form of interoceptive exposure. Interoceptive exposure involves providing exposure to feared physiological sensations to reduce the fear of the sensations (Stewart & Watt, 2008). There are many proposed mechanisms to explain how interoceptive exposure reduces anxiety including via conditioning (i.e., extinction by experiencing the feared anxiety sensations without the associated negative consequence of having a panic attack), cognitive restructuring (i.e., challenging irrational beliefs), emotional processing (i.e., altering fear structure and memory), social learning (i.e., building self-efficacy that an individual can manage feared situation), and acceptance (i.e., learning to accept anxiety-related experiences) (for a review, see Stewart & Watt, 2008). Ultimately, these proposed mechanisms share that exposure to the feared physiological experience provides opportunities for change in a psychological process. At the same time, avoidance of these sensations likely strengthens the maladaptive thoughts, beliefs, or other psychological processes that maintain anxiety-related concerns whereas exposure to these

sensations counteracts this maintenance of fear of the sensations. Although the results of this dissertation cannot prove causation, they support the idea that those who are exposed to more arousal sensations, at least those generated from physical activity, experience less anxiety sensitivity.

Although the present study supported current conceptualizations of anxiety sensitivity as it relates to physical activity behaviour, it is important to note that there has been debate surrounding the construct of anxiety sensitivity. In one study examining the measurement of anxiety sensitivity, Norton et al. (2017) assessed whether anxiety sensitivity, as measured using an unpublished measure of anxiety sensitivity (i.e., the Anxiety Sensitivity Index-Revised-Modified), was in fact a distinct fear of anxiety-related sensations or if it was capturing a fear of somatic sensations more broadly. Confirmatory factor analyses failed to provide clear support for either fear of anxiety-related sensations and fear of non-anxiety-related sensations as the same construct or as differing constructs. Anxiety sensitivity and fear of non-anxiety-related sensations similarly predicted hypochondriacal fears; however, anxiety sensitivity had a stronger association with panic severity. The authors concluded that anxiety sensitivity may be a specific subset of a broader fear of physiological sensations. Thus, in the context of this dissertation, it is important to recognize that the lower levels of physical activity seen in those with higher anxiety sensitivity scores may be the result of anxiety-specific fears, and/or broader fears of interoceptive sensations that include, but are not limited to, anxiety sensations.

The notion that anxiety sensitivity is a specific component of broader interoceptive sensitivity (Norton et al., 2017) aligns with the results across the dissertation studies. Perhaps the significant although small relationship between anxiety sensitivity and physical activity found in Study 1 and Study 2, as well as the moderate anxiety sensitivity levels found in Study 3 despite

participants being highly physically active reflects the anxiety-specific nature of anxiety sensitivity. That is, although sensations associated with anxiety occur during physical activity, they are not completely the same. Anxiety-specific sensations are only a part of the entire experience associated with physical activity. For example, sensations of muscular fatigue, commonly experienced during physical activity, would not be theoretically feared by individuals with elevated anxiety sensitivity but might be by those with a broader interoceptive sensitivity. As well, research has suggested that domain-specific anxiety sensitivity is an important consideration and has more utility in predicting specific behaviours (e.g., sexual anxiety sensitivity in predicting sexual avoidance; Byers et al., 2022).

Recently, Farris and colleagues (2020) noted the overlap between anxiety-related sensations and exercise sensations while acknowledging that there are sensations that occur during exercise that are not captured as part of anxiety sensitivity, although both may be part of a broader interoceptive sensitivity (Norton et al., 2017). Nonetheless, participants in a qualitative study have described the connection between the physiological sensations experienced during exercise and those experienced when anxious (e.g., sweating, shaking) and indicated that this association led to their increased avoidance of exercise (Mason et al., 2019). To assess sensitivity specific to exercise, Farris and colleagues (2020) developed the Exercise Sensitivity Questionnaire (ESQ) as a measure of 'exercise sensitivity'. It is important to note that the sample used for the development of this measure involved those at risk of, or already experiencing, cardiovascular disease. The ESQ has two subfactors, one that assesses a fear of cardiopulmonary exercise sensations and another that assesses fear of pain/weakness exercise sensations. The study involved two separate samples (sample 1 $N = 252$; sample 2 $N = 50$) as well as a subsample ($n = 12$) from one of the main samples. In their larger sample, the results indicated the

total ESQ score was inversely associated with physical activity. When examining the association between ESQ subfactors and physical activity, the study revealed a significant inverse association between physical activity and the cardiopulmonary sensitivity subscale. No significant relationship between physical activity and the pain/weakness sensitivity subscale was found. Theoretically, the cardiopulmonary sensitivity subscale more strongly aligns with the anxiety sensitivity construct as they capture many similar sensations. Thus, although broader and/or distinct sensitivities may be involved in lower levels of physical activity, there is evidence that anxiety sensitivity itself, and theoretically shared components with other sensitivities, contribute.

Finally, the results of this dissertation align with research and theory on affective determinants of physical activity. In the Affect and Health Behaviour Framework (AHBF; Williams & Evans, 2014), there are four classifications of affective variables that impact the occurrence of health behaviours. These are the affective response to a health behaviour, incidental affect or the affect an individual experiences outside of the context of the health behaviour, affect processing or the cognitive processing of affect, and affectively charged motivation (Stevens et al., 2020; Williams & Evans, 2014). Anxiety sensitivity is considered a part of affectively charged motivation with respect to participation in physical activity (Stevens et al., 2020). Theoretically, anxiety sensitivity increases fear of physical activity, and this fear reduces motivation to engage in physical activity. With reduced motivation to engage in the behaviour, individuals are less likely to participate in it. This model can help explain the inverse relationship between physical activity and anxiety sensitivity. The model may also help to explain why athletes engage in high levels of physical activity despite having moderate levels of anxiety sensitivity on average (Study 3). With much of their physical activity occurring in the

context of sport, perhaps athletes experience more positive affect during physical activity (e.g., scoring a goal when exerting themselves) and have more helpful processing of affective experiences during sport (e.g., remembering the joy of winning an important game). In other words, although anxiety sensitivity may be one barrier to their physical activity participation, they have several other potentially saliant affective mechanisms promoting their physical activity participation.

Clinical Implications

Anxiety sensitivity and physical activity each have widespread health implications. Both are associated with numerous physical and mental health outcomes (e.g., Goodwin, 2003; Warburton et al., 2006). Understanding their inter-relationship provides insight that could improve future health promotion efforts. The inverse association between anxiety sensitivity and physical activity found in Study 1 and Study 2 suggest that anxiety sensitivity may be a helpful target for physical activity promotion efforts. Additionally, Study 2 results suggest targeting anxiety sensitivity in women may be particularly helpful for reducing the gender gap in physical activity participation. Fortunately, anxiety sensitivity can be reduced using brief interventions (Fitzgerald et al., 2021), telephone delivered interventions (Olthuis, Watt, Mackinnon et al., 2014), and even single exercise sessions (LeBouthillier & Asmundson, 2015). Such interventions may be helpful for the large number of Canadians who fail to achieve the minimum recommended levels of physical activity participation (Statistics Canada, 2021). The results of this dissertation have shown that the inverse relationship between anxiety sensitivity and physical activity is present in general population samples that capture a spectrum of anxiety sensitivity levels, not just samples recruited on high anxiety sensitivity. Study 1 results suggest that the relationship may even be stronger in non-clinical samples who tend to have lower

anxiety sensitivity levels (Naragon-Gainey, 2010; Olatunji & Wolitzky-Taylor, 2009). Thus, such anxiety sensitivity-targeted interventions for promoting physical activity may be applicable for a broad group of people.

In support of targeting anxiety sensitivity for physical activity promotion, research has shown that barriers to physical activity participation play a large role in determining physical activity levels. When examining barriers to and benefits of physical activity participation, Sabourin et al. (2011) found than anxiety sensitivity was positively correlated with perceived barriers to exercise. This makes sense theoretically, as increased anxiety sensitivity and accompanying fears of some of the physiological sensations experienced during physical activity would serve to be an additional barrier. Interestingly, the same study found that anxiety sensitivity was positively associated with perceived benefits of physical activity participation as well. Despite perceiving more benefits from physical activity, the individuals with elevated anxiety sensitivity engaged in less physical activity than their counterparts who were lower in anxiety sensitivity. Taken together, these results show that individuals with elevated anxiety sensitivity perceive more benefits of physical activity yet engage in it less because the perceived barriers are too influential. Thus, targeting elevated anxiety sensitivity, a known barrier for physical activity participation, seems to be a promising avenue worth exploring.

As mentioned previously, only one prior study has attempted to evaluate the impact of reducing anxiety sensitivity on physical activity participation (Lanoye et al., 2022). Lanoye et al. (2022) based their intervention on two-week protocols known to be sufficient to reduce anxiety sensitivity (Broman-Fulks et al., 2004; Broman-Fulks & Storey, 2008) and compared the effects to a control group that only completed assessments at the same time points (i.e., did not participate in exercise, receive psychoeducation, or instruction to change their physical activity).

They assessed anxiety sensitivity and physical activity at baseline, at the end of the two-week intervention, two weeks post-intervention, and six weeks post-intervention. When assessing changes in anxiety sensitivity over the four time points, the results failed to show a significant group by time interaction, suggesting anxiety sensitivity levels over time were comparable between the intervention group and the control group. The researchers re-ran the analysis after removing the 6-week post-treatment follow up data. After this adjustment, their results showed a marginal time by group (control vs. intervention) interaction effect on anxiety sensitivity (p = .06). However, change in anxiety sensitivity for the intervention group from baseline to two weeks post-treatment represented a medium effect size (d = .4), possibly indicating the study was under powered. When examining changes in physical activity levels, both the intervention and control groups had lower physical activity levels over time, with no significant differences in change between groups. Taken together, these results are difficult to interpret given a) non-significant changes in anxiety sensitivity for the experimental group and b) significant changes in physical activity levels for the control group. Thus, future research examining the impact of an anxiety sensitivity reduction program on physical activity participation is required with a larger sample size to ensure adequate power for detecting the predicted interactions. Nonetheless, when asked in an interview, participants who completed a running program that reduced anxiety sensitivity reported increases in physical activity following the program (Olthuis et al., 2020).

Although anxiety sensitivity appears to be a promising intervention target for physical activity promotion, it is likely that additional strategies or intervention components are necessary. Lanoye et al. (2022) suggested that future research examine the potential benefit of using exercise alongside additional interventions such as goal setting to increase physical activity behaviour. As one example, participants in a qualitative study by Mason et al. (2019) described

anxiety coming from a lack of gym knowledge (e.g., not knowing how to safely participate in exercise and follow norms associated with exercising in a gym) as a barrier to their physical activity participation. Providing education and guidance on appropriate exercise approaches would likely be beneficial as an additional component to such interventions.

In addition to suggesting that reducing anxiety sensitivity might have implications for physical activity, the results of this dissertation suggest that increasing physical activity may be beneficial for those who have elevated anxiety sensitivity. This aligns with several studies showing that physical activity reduces anxiety sensitivity (Jacquart et al., 2019). Unfortunately, it appears as though many mental health professionals do not receive any training on the use of physical activity for improving mental health in their clients. Research suggests, for example, that there is a lack of information on physical activity and mental health in clinical psychology doctoral programs (Faulkner & Biddle, 2001). Similarly, one study showed that despite acknowledging the benefits of exercise, staff in an inpatient mental health setting (e.g., psychologists, mental health nurses, occupational therapists) felt they did not have the training to implement exercise and did not consider it as a specific treatment component for improving mental health (Ball et al., 2022).

It appears physical activity is an under-utilized intervention in mental health treatment, despite the wide-ranging benefits. In a survey study of psychologists and their willingness to integrate exercise into treatment plans, 83% reported recommending physical activity (Burton et al., 2010). However, the response rate was only 38% and it is possible that psychologists who promoted physical activity were more likely to respond to the survey. Engaging in regular exercise oneself, having confidence in providing general activity advice, being in private practice, patients' acceptance of activity information from a psychologist, and having patients

with general health and well-being concerns were factors positively associated with providing physical activity advice to patients (Burton et al., 2010). Another study of therapists showed that 58.7% provide verbal recommendations for physical activity, but only 3.1% reported frequently providing this information in written form (Mailey et al., 2022). In the same study, most therapists indicated that physical activity was important for mental health, although fewer reported being comfortable counselling clients about physical activity or knew the physical activity guidelines.

Fortunately, when psychologists were asked if they were interested in attending a workshop on providing advice or counselling related to physical activity, 72% reported a high interest in such a training opportunity (Burton et al., 2010). Therefore, providing education to clinicians on the benefits of physical activity for improving mental health and how to incorporate this into treatment plans appears to be a promising option for improving the clinical care of patients. Such training could include graduate coursework, supervised training, or continuing education workshops.

Finally, the results of Study 3, demonstrating that anxiety sensitivity operates as a transdiagnostic construct among athletes, have clinical implications for the treatment of athlete mental health. Clinicians working with athletes experiencing mental health concerns may wish to assess anxiety sensitivity to determine if it is a worthwhile treatment target, given its associations with emotional disorder symptoms. Fortunately, the Anxiety Sensitivity Index – 3is validated in athletes (DeWolfe et al., 2022). If elevated scores are detected, anxiety sensitivity intervention may be warranted.

Unfortunately, there is a lack of high-quality athlete-specific research on mental health interventions (Ekelund et al., 2022) and a need has been identified for athlete-specific mental

health research (Hughes & Leavey, 2012; Reardon & Factor, 2010; Rice et al., 2016). The lack of athlete-specific research is problematic given that there are several factors related to participation in sports that may impact the development of mental health symptoms (Rice et al., 2016) as mentioned in Study 3. Accordingly, the directions for future research, discussed above, include examining the impact of anxiety sensitivity interventions for athletes. In the meantime, evidence-based protocols for general samples exist, and could be applied to athletes. Such interventions are helpful in reducing symptoms across disorders (Olthuis, Watt, Mackinnon et al., 2014), but have also been shown to be effective as a preventative treatment option (Schmidt et al., 2007). As such, targeting anxiety sensitivity in athletes may reduce symptoms across disorders (e.g., for an athlete struggling with both anxiety and depression). It may also facilitate the use of group-based interventions; a single anxiety sensitivity focused group intervention could help individuals experiencing a variety of mental health concerns. This would: a) make it easier for clinicians to have sufficient clients to run a group; and b) simplify the demands on clinicians (e.g., by reducing the amount of content they need to know or consult to prepare for groups).

Clinically, the results of Study 3 also highlight the complexity of mental health. Although athletes in Study 3 engaged in high levels of physical activity through their high-performance sport participation, they were not without symptoms of various emotional disorders. On average, athletes in Study 3 tended to have higher levels of social anxiety and depressive symptoms, and a higher percentage reported past year panic attacks than previously tested non-clinical samples (Lebeau et al., 2012; Seeley-Wait et al., 2009; Kroenke et al., 2001; Martens et al., 2006; Norton et al., 2008). In other words, engaging in a high level of physical activity alone was insufficient to prevent mental health concerns. Thus, although this dissertation highlights the important role

physical activity has in mental health, clinicians should consider physical activity as one important factor contributing to mental health to be considered in a broader case conceptualization alongside other factors.

Indeed, clinicians need to be aware of how, in certain situations, physical activity may contribute to mental health concerns. Sport participation involves additional stressors that may negatively impact mental health (Rice et al., 2016). For example, poor performances in elite athletes can increase risk for depressive symptoms (Hammond et al., 2013). Recent research also shows that having a strong physical activity identity may make individuals more susceptible to anxiety and depressive symptoms when they are unable to exercise (e.g., an athlete who is injured; Forshaw et al., 2023). Individuals may also experience exercise addiction – a behavioural addiction where individuals persist with excessive exercise despite experiencing negative physical (e.g., injury), psychological (e.g., anxiety), and social (e.g., conflict) consequences. Individuals experiencing exercise addiction may also suffer from exercise withdrawal symptoms (e.g., increased anxiety, irritability; Juwono & Szabo, 2021; Landolfi, 2013) when not exercising. Furthermore, there is evidence to suggest that individuals with elevated risk for exercise addiction experience elevated rates of other mental health problems including eating disorders, anxiety, and other addictive disorders (Colledge et al., 2020). In eating disorders, exercise can be particularly problematic as it can maintain eating disorder symptoms (Meyer et al., 2011; Rizk et al., 2020) and interfere with weight gain that is necessary to prevent serious physical health consequences in low weight individuals.

Conclusion

In conclusion, anxiety sensitivity, physical activity, and mental health are clearly linked. This dissertation has clarified the links between anxiety sensitivity and physical activity and

shown that the associations between anxiety sensitivity and emotional disorder symptoms remain in a highly physically active group. This research clarified, replicated, and added novel insights to the existing literature. The results help to open the door for future research to examine the impact of anxiety sensitivity interventions for improving physical activity levels and associated health outcomes. It also provides support for anxiety sensitivity as a transdiagnostic mental health treatment target for athletes. Clinical implications of this research are widespread in terms of their potential for improving both mental and physical health outcomes.

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APPENDIX A. STUDIES WHERE INCLUSION CRITERIA FOR STUDY 1 WERE MET BUT DATA WERE UNAVAILABLE

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APPENDIX B. STUDIES INCLUDED IN STUDY 1 META-ANALYSIS

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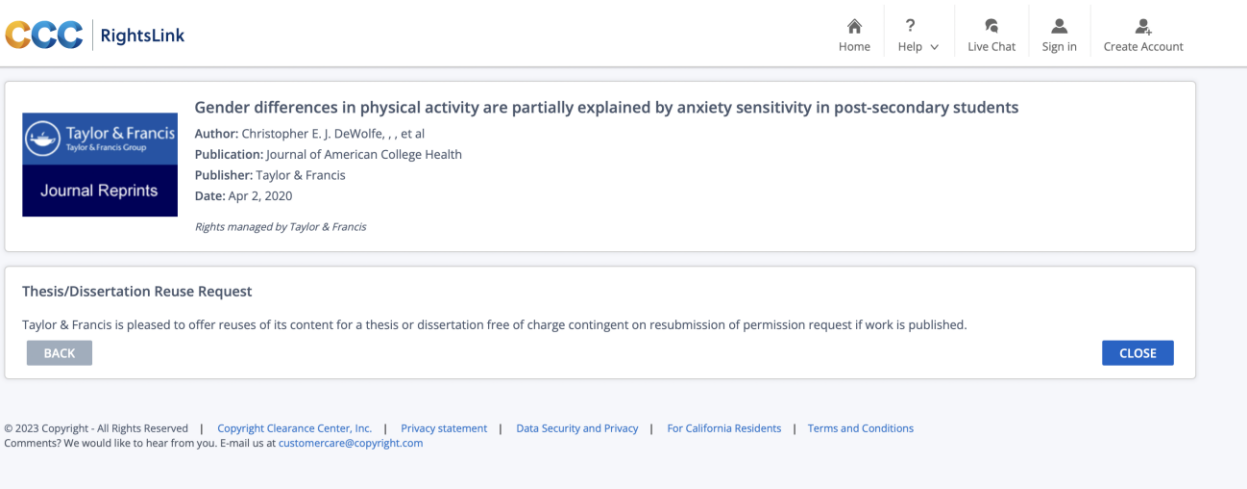
APPENDIX C: PERMISSION TO INCLUDE STUDY 2

This is based on an accepted manuscript of an article published by Taylor & Francis in Journal of American College Health on January 15th, 2019, available online: http://wwww.tandfonline.com/10.1080/07448481.2018.1549048 or https://doi.org/10.1080/07448481.2018.1549048



APPENDIX D: PERMISSION TO INCLUDE STUDY 1

Study 1 is based on a manuscript published by Elsevier in the journal Mental Health and Physical Activity on August 9th, 2023, available online:

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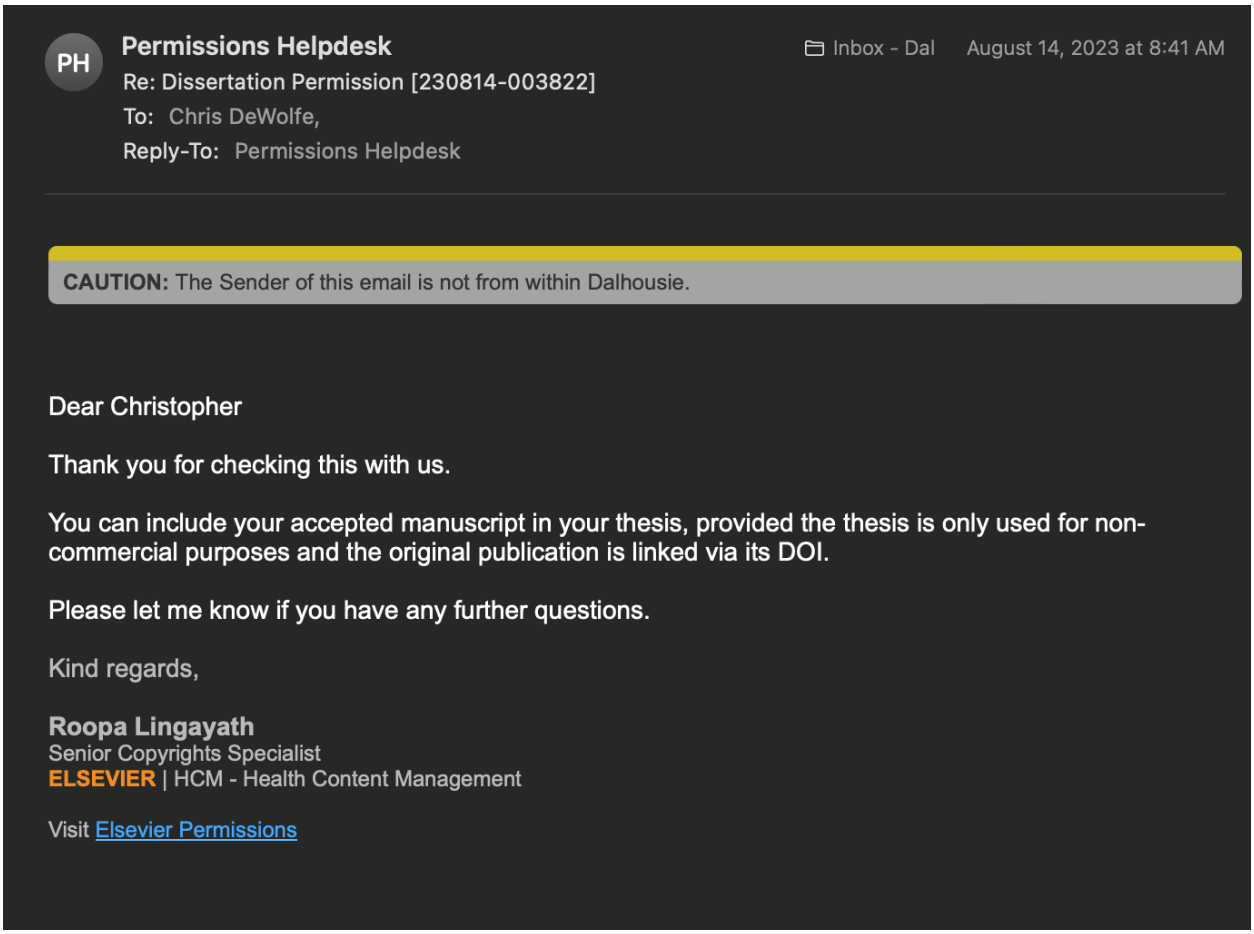

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