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Cognitive Vulnerability to Mood Disturbance in an Exercise Withdrawal Paradigm

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COGNITIVE VULNERABILITY TO MOOD DISTURBANCE IN AN EXERCISE WITHDRAWAL PARADIGM

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ABSTRACT

Depressive symptoms are more common among sedentary individuals with longitudinal studies supporting inactivity as a potential risk factor for mood disturbances. Observational and experimental designs find that lack of exercise or exercise deprivation is associated with increased depressive and anxiety symptoms, fatigue, and pain. However, literature has not examined risk factors influencing mood deterioration in response to exercise deprivation. The current study tested the hypothesis that physically active individuals with high levels of cognitive vulnerability (i.e., a tendency towards negative thought content and processes when under stress) are at high risk for mood disturbance when undergoing exercise cessation. Community adults who met guidelines for recommended physical activity (*N*=36) were examined in a 4-week prospective, longitudinal study. Mood was assessed with the Beck Depression Inventory-Second Edition, the Beck Anxiety Inventory, and the Brief Profile of Mood States at baseline, after two weeks of maintained exercise, and after one and two weeks of exercise cessation. Cognitive vulnerability variables (i.e., dysfunctional attitudes, brooding rumination, cognitive reactivity) were assessed following the maintained exercise phase. Similar to prior studies, results indicated a main effect of time, such that depressive and anxiety symptoms increased over the exercise cessation protocol. Results additionally lend support for a vulnerability-stress model, with brooding rumination identified as a risk factor for the development of symptoms during exercise deprivation. This study suggests that individuals who engage in brooding rumination to cope with negative affect are at elevated risk for mood symptoms when ceasing their exercise routine.

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CHAPTER 1: INTRODUCTION

1.1. Study Overview

The lifetime prevalence of Major Depressive Disorder (MDD) is around 16% (Kessler et al., 2003), making MDD one of the most prevalent mental illnesses and a major disability problem worldwide. Depressive symptoms are more prevalent among sedentary compared to physically active individuals (Dunn, Trivedi, & O'Neal, 2001; Mobily, Rubenstein, Lemke, & Wallace, 1996; Weyerer, 1996). Longitudinal studies suggest that physical inactivity may be a risk factor for future mood disturbances, and greater exercise has shown to be predictive of reduced depressive symptoms over time (Farmer et al., 1988; Pinto Pereira, Geoffroy, & Power, 2014). In habitual exercisers, laboratory studies involving exercise deprivation and observational studies comparing exercise vs. non-exercise days find that lack of exercise is associated with increased depressive and anxiety symptoms, fatigue, and pain (Berlin, Kop, & Deuster, 2006; Conboy, 1994; Glass et al., 2004; Mondin et al., 1996). However, it is unknown why mood deteriorates in response to exercise withdrawal and who is most at risk for these effects.

The current study integrates research and theory from unipolar depression and exercise science to identify potential mechanisms and moderators that may explain vulnerability to mood symptomatology in the face of reduced physical activity. This work has widespread implications for populations at risk for mood symptoms and affective disorders while undergoing exercise cessation when faced with stressors such as developmental transitions, injury, medical conditions, pregnancy, and lifestyle changes.

Using an exercise withdrawal paradigm, this study tests a vulnerability-stress model that conceptualizes exercise cessation as a stressor that interacts with a putative cognitive vulnerability to depression to elicit depressive and anxiety symptoms. According to the model, individuals who have a cognitive vulnerability to depression (i.e., a tendency towards negative thought content and processes in reaction to stress and/or transient dysphoric mood) are most likely to develop depressive and anxiety symptoms under conditions of exercise deprivation. The model incorporates cognitive vulnerability constructs drawn from established cognitive theories of depression, including cognitive reactivity (i.e., a negative shift in thinking in response to sad mood; Segal, Gemar, & Williams, 1999; Segal et al., 2006), dysfunctional attitudes (i.e., maladaptive rules and assumptions; Beck, 1967; 1976), and rumination (i.e., the tendency to repetitively focus attention on depressed mood and its causes and consequences; Nolen-Hoeksema, 1987; 1991). Research supports these constructs as cognitive vulnerabilities that increase one's risk for future development of MDD and for an increase in depressive symptoms over time (Alloy et al., 2006; Hankin, Abramson, Miller, & Haeffel, 2004; Kwon & Oei, 1992; Lewinsohn, Joiner, & Rohde, 2001; Nolan, Roberts, & Gotlib, 1998; Nolen-Hoeksema, 2000; Nolen-Hoeksema & Davis, 1999; Nolen-Hoeksema, Larson, & Grayson, 1999; Nolen-Hoeksema & Morrow, 1991; Nolen-Hoeksema, Parker, & Larson, 1994; Sarin, Abela, & Auerbach, 2005; Segal et al., 1999; 2006; Wood, Saltzberg, Neale, Stone, & Rachmiel, 1990). Exercise withdrawal-related mood disturbance is an established phenomenon; however, no prior study has integrated cognitive theory to test cognitive vulnerability as a potential mechanism of these effects.

This project tested this model using a prospective, longitudinal design with 36 community adults who met the American College of Sports Medicine (ACSM) recommended guidelines for physical activity level (Haskell et al., 2007). Participants were assessed at baseline (study visit 1), and following two weeks of maintained exercise (study visit 2), to verify continued exercise at or above the minimum threshold per ACSM guidelines. At the second study visit, participants completed measures assessing cognitive vulnerability constructs, including cognitive reactivity to a dysphoric mood induction, the Dysfunctional Attitudes Scale, and the Ruminative Response Scale, before undergoing two weeks of voluntary exercise cessation. Mood was measured with the Beck Depression Inventory-Second Edition, the Beck Anxiety Inventory, and the Brief Profile of Mood States at baseline (study visit 1), after two weeks of maintained exercise (study visit 2), and after two weeks of exercise cessation (study visit 3). Participants additionally completed mood outcome measures after one week of exercise cessation (mail-in questionnaire assessment).

To provide relevant background for the current study, research on the association between exercise and psychological well-being, and previous studies on the effects of exercise cessation on mood are reviewed below. Additionally, relevant literature pertaining to cognitive vulnerability constructs and the vulnerability-stress model is presented.

1.2. Physical Activity and Mental Health

Physical activity has important mental health benefits. Adults who engage in regular physical activity, per the guidelines defined by the U.S. Department of Health and Human Services, are at lower risk for depression and cognitive decline (USDHHS, 2008).

In general, higher levels of exercise are associated with lower depressive and anxiety symptoms, and exercise interventions have shown antidepressant and anxiolytic effects (Blake, Mo, Malik, & Thomas, 2009; Salmon, 2001; Teychenne, Ball, & Salmson, 2008). Research has examined the impact of exercise on psychological wellbeing in studies examining positive affect, as well the effects of physical activity on depressive and anxiety symptoms.

1.2.1. Exercise and Positive Affect

A relationship between aerobic physical activity and positive affect has been well-documented in qualitative, cross-sectional, longitudinal, and experimental studies. A meta-analysis conducted by Reed and Ones (2006) sought to examine the relationship between acute physical activity and what they termed "positively activated affect" (PAA) in 158 studies conducted between 1979 and 2005. Studies utilized self-report scales that the authors deemed to be appropriate measures of PAA (e.g., Positive Affect Scale of the Positive and Negative Affect Schedule, Pleasantness and Activation subscales of Mood Adjective Checklist). The effect size for the presence of aerobic exercise on increased PAA was nearly one-half of a standard deviation higher after exercise than before (d = .45; 95% CI: .40 to .50), suggesting a significant impact of physical activity on positive affect. For instance, in a study conducted by Gauvin, Rejeski, and Norris (1996), adult women were studied for 6 weeks and provided affect and feeling state measures when randomly prompted (4 times per day) and prior to and after acute bouts of physical activity. Engagement in physical activity was associated with significant increases in positive affect, with additional studies finding further support for this relationship

(Bossmann, Kanning, Koudela-Hamila, Hey, & Ebner-Priemer, 2013; Fortier, Guerin, Williams, & Strachan, 2015; Magman, Kwan, & Bryon, 2013).

Additionally, Reed and Ones (2006) found that lower baseline affect pre-exercise was associated with even greater improvements in PAA compared to higher baseline levels. This finding supports engagement in physical activity as a self-regulatory strategy for individuals to increase energy and positive affect (Reed & Ones, 2006; Thayer, 1996). A more recent study suggests these effects may be most apparent in clinically depressed patients. In a naturalistic study utilizing experience sampling, Mata and colleagues (2012) studied 53 adults with MDD and 53 healthy controls over a 7-day period. Participants were prompted eight times per day for self-initiated physical activity and affect reports. Contrary to the authors' hypotheses, the groups were not significantly different on overall levels of physical activity. Across all participants, positive affect increased following physical activity. However, in depressed participants, a more pronounced dose-response relationship was found, indicating that the effect of high intensity and longer duration physical activity on positive affect may be stronger for individuals with lower levels of initial mood status.

A subsequent meta-analysis conducted by Reed and Buck (2009) examined the effect of regular exercise on self-reported PAA in 105 studies conducted between 1980 and 2008. Similar to findings for acute physical activity, regular aerobic exercise resulted in moderate increases in positive affect, particularly when baseline affect was below average.

1.2.2. Exercise and Depressive Symptoms

Cross-sectional studies examining the relationship between physical activity and levels of depression have historically found that lower levels of exercise are associated with higher depressive symptoms (for review see Dunn, Trivedi, & O'Neal, 2001). For instance, in a large cross-sectional analysis, adults who reported no physical activity were 3.15 times more likely to have moderate to severe depression compared to regular exercisers (Weyerer, 1992). Additional work has replicated the association between sedentary behavior and depression, providing robust support for a correlation between exercise and mood symptomatology (Bhui & Fletcher, 2000; Hassman et al., 2000; Krause et al., 1993; Kivela and Pahkala, 1991; Pennix et al., 1999; Pinto Pereira, Geoffroy, & Power, 2014; Ruuskanen and Ruoppila, 1995; Stephens, 1988). However, from these studies, conclusions cannot be drawn as to the temporal relationship between the two (i.e., if low physical activity leads to depression, if depressive symptoms lead to a lack of physical activity, or if a third variable accounts for the association).

Prospective studies evaluating the causal relationship between physical activity and depressive symptoms indicate that low levels of exercise predict subsequent depression (Dunn et al., 2001). In a study by Farmer and colleagues (1988) that utilized epidemiological data, low levels of exercise were associated with the development of depressive symptoms at an 8-year follow-up in women only. In another study by Pinto Pereira, Geoffroy, and Power (2014) data on physical activity and depressive symptoms was collected over time from 18,558 individuals at the ages of 23, 33, 42, and 50 years. Longitudinal analyses from this study indicated that a greater frequency of exercise was predictive of decreased depressive symptoms over time, across early to mid-adulthood. This study furthermore found a bidirectional relationship between the variables, with the strongest association in young adulthood, such that depressive symptoms were associated with decreased physical activity over time. Findings from these studies have been replicated implicating physical activity as a causal factor in the development of mood symptomatology (Camacho, Roberts, Lazarus, Kaplan, & Cohen, 1991; Jacka, et al., 2011; Lampinen, Heikkinen, & Ruoppila, 2000; Paffenbarger, Lee, & Leung, 1994; Stewart et al., 1994).

Clinical trials examining the efficacy of exercise interventions for depressive symptoms point towards the effectiveness of exercise in reducing symptoms. In a review by Cooney, Dwan, and Mead (2014), authors examined 39 randomized clinical trials comparing exercise vs. no treatment, antidepressant medications, or psychological therapies. They found that relative to a control group, exercise was associated with a decrease in depression (i.e., approximately 5 BDI points), representing a moderate effect of exercise as an intervention for depressive symptoms, including studies utilizing individuals who met diagnostic criteria for MDD. However, the authors found methodological flaws with many of the trials reviewed, and in the subsample (n=6) of studies that used more rigorous methodological designs (i.e., intent-to-treat analyses, blind outcome assessments), there was no association between exercise and depression scores. They concluded that exercise may have a moderate-sized association with decreased depression, but recommended further studies with larger samples, using high-quality designs to examine this relationship. Another meta-analysis using only randomized controlled trials comparing exercise with no treatment or placebo groups, found a large antidepressant effect for exercise as an intervention (Josefson, Lindwall, & Archer, 2014). Similar to the review by Cooney et al. (2014), Josefson et al. found that when using the subsample of trials with high methodological integrity, the effect reduced to a more moderate size, and concluded that exercise has at best a strong effect, and at worst a moderate effect, in reducing depressive symptoms.

In conclusion, although certain studies have failed to find antidepressant effects of exercise (e.g., Chalder et al., 2012), cross-sectional and longitudinal designs, as well as clinical trials for exercise, support a negative association between physical activity and depressive symptoms.

1.2.3. Exercise and Anxiety Symptoms

Less research has been conducted on the association between exercise and anxiety symptoms, but cross-sectional studies suggest a relationship between exercise and decreased anxiety. A study conducted by Goodwin (2003), examined epidemiological nationally representative data from The National Comorbidity Survey, comprised of 8,098 U.S. residents aged 15 to 54. Participants were asked about their frequency of engagement in physical activity at work or home (i.e., regularly, occasionally, rarely, never) and underwent interviews assessing psychiatric diagnoses over the past 12 months. Engagement in physical activity on a regular basis was associated with a decreased likelihood of a number of diagnoses, including the following anxiety disorders/conditions, with results continuing to be significant after controlling for sociodemographic variables and physical illnesses: generalized anxiety disorder, social anxiety disorder, agoraphobia, panic attacks, specific phobia, as well as MDD. A second population study using a sample of 19,288 adults found an association between exercise and lower anxiety levels, as well as less depression and neuroticism (De Moor, Beem, Stubbe, Doomsma, & De Geus, 2006).

Studies examining the effects of exercise interventions on anxiety symptoms have yielded mixed results. A meta-analysis by Bartley, Hay, and Block (2013) examined the effectiveness of exercise as an intervention for DSM-IV diagnosed anxiety disorders with 7 randomized clinical trials and a total of 407 participants included in the analyses. Results indicated that aerobic exercise did not have a significant effect on anxiety symptoms in populations with anxiety disorders. However, secondary analyses suggested the moderating role of study design on intervention efficacy. Studies comparing exercise to placebo or control conditions found a significant anxiolytic effects of exercise (e.g., Broocks et al., 1998), whereas head-to-head trials comparing exercise to psychotherapy or pharmacotherapy found a significant difference, or a non-significant trend, supporting the comparison treatment over exercise in reducing anxiety symptoms (e.g., Hovland et al., 2012). Despite this conclusion, a number of studies demonstrate promise for exercise as an intervention for various anxiety disorders, and additional studies with more rigorous designs are needed to further examine the effects of exercise interventions on anxiety symptoms (for review see Asmundson et al., 2013). A more recent meta-analysis by Stonerock, Hoffman, Smith, & Blumenthal (2015) reviewed 12 randomized clinical trials and 5 meta-analyses (including Bartley et al., 2013) with samples of clinical anxiety disorders, and found similar mixed results. These authors concluded that exercise appeared effective in reducing anxiety symptoms in the majority of studies, with anxiolytic effects similar to established interventions and better than placebo control groups. Stonerock et al. suggested further research to elucidate this relationship, given validity and methodological concerns with reviewed trials, such as concurrent interventions for anxiety symptoms in the same treatment group, small sample sizes, potential for reporting or experimenter bias, and lack of assessment of exercise intervention adherence. In healthy non-clinical samples, a meta-analysis of 19 studies examining a range of exercise interventions found a small to moderate effect of exercise on anxiety symptoms, suggesting generalization of such anxiolytic effects to non-clinical populations (Conn, 2010).

In summary, relative to literature supporting the antidepressant effects of exercise, research on the association between exercise and anxiety levels are more mixed. Overall, research supports an association between increased exercise and lower levels of anxiety symptoms in observational designs, as well as some evidence for the anxiolytic effects of exercise in clinical trials with anxiety disorder and non-clinical populations.

1.3. Existing Exercise Withdrawal Literature

Correlational studies and experimental designs focused on lack of exercise or exercise deprivation have further investigated the association between exercise and psychological well-being. Given that this literature serves as the basis for the current study, prior studies are reviewed in detail below, with particular focus on mood constructs that have previously been examined.

1.3.1. Correlational Studies

Within the exercise withdrawal literature, studies utilizing cross-sectional designs support an association between exercise cessation and mental health. In one such study, Conboy (1994) assessed 61 habitual runners for up to 15 consecutive days. Participants completed the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1971; 1992) as a measure of their mood on days that they ran and on days that they did not run, with each participant required to report on at least 10 run and 2 no-run days. On days that participants ran, they were asked to complete the POMS between 20 and 40 minutes after finishing exercise, and on days that they did not run, they were asked to complete the POMS at the same time as they had done so on the previous day. Results indicated greater mood disturbances on no-run days relative to run days, including higher total mood disturbance, depression, anger, fatigue, and confusion and decreased vigor. Conboy concluded that among people who engage in significant running (the average runner in his study ran 33 miles per week over the course of 6 runs), running is associated with psychological benefits, whereas a failure to run is associated with dysphoria, although causality in this study cannot be determined. Use of a well-validated measure, the POMS, to assess psychological well-being is a strength of the study. Limitations to the study include failure to define physical activity criteria for participant inclusion, a non-randomized design, and repeated sampling with the same measure, which may have resulted in testing effects. Results from a similar study comparing exercise vs. non-exercise days support these findings, with the majority of participants reporting psychological distress (i.e., irritability, restlessness, frustration, guilt, and depression) on days in which they did not engage in their running routine (Robbins & Joseph, 1985).

In another study utilizing a naturalistic design, Johnston and Carroll (2000) assessed 93 individuals who had suffered injury and had a minimum of 21 days of restriction from engagement in sports and/or normal functioning. Participants were assessed at their initial intake appointment for rehabilitation therapy, halfway through treatment, and at their final appointment, with six visual analogue scales corresponding to the six subscales of the POMS: anxiety, anger, depression, confusion, energy, and fatigue. Results from this study indicated that anxiety, anger, depression, confusion, and fatigue decreased, whereas energy increased, over the exercise withdrawal period. Johnston and Carroll found that participants who were more involved in sports, determined by the number of hours they spent in their activities prior to injury, were more likely to experience confusion over the course of the study and viewed their recovery as less complete at the end of treatment relative to those who were less involved in sports, implying the emotional response to injury and/or to exercise-induced exercise cessation may be greater for highly active individuals. Although this study adds to the literature on the effects of exercise withdrawal on subsequent mood disturbance, it may be more informative of the trajectory of mood symptomatology over course of rehabilitation rather than over the course of exercise cessation because injury and exercise cessation are confounded in the design. There was no assessment of baseline psychological well-being prior to injury or of exercise cessation in the absence of injury, which would serve as the necessary comparisons to draw such conclusions. Limitations to this study include failure to assess mood and physical activity level prior to injury, a non-randomized design, non-generalizability beyond athletes, and the use of a 6-item questionnaire to measure mood. In a very similar observational design, Chan and Grossman (1988) examined 60 regular runners, 30 of whom were injured and were unable to run for at least 2 weeks (termed "Prevented Runners"). These authors found that the Prevented Runners reported significantly higher depression, tension, confusion, overall mood disturbance, and lower self-esteem compared to the continued exercise group.

1.3.2. Experimental Designs

A small number of studies have examined the effects of exercise cessation on mood symptomatology using experimental designs with longitudinal follow-up. In the first published experimental design, a month of physical activity withdrawal had significant mental health effects, including increased tension, anxiety, and disturbance of sleep (Baekeland, 1970). Subsequent experimental studies support the conclusion that exercise cessation leads to psychological effects across a range of deprivation periods from 24 hours (Thaxton, 1982) to 14 days (Berlin et al., 2006; Morris, Steinberg, Sykes, & Salmon, 1990).

In one such study, Mondin and colleagues (1996) assessed ten habitual exercisers over a 5-day period, with habitual exercise defined as engaging in at least 45 minutes of exercise on 6-7 days per week. Participants were required to refrain from physical activity for 3 days and were assessed daily over the course of 5 days, including one day prior to and one day after the exercise cessation phase. In addition to the requirement to forgo their regular exercise routines, participants were asked to minimize their lifestyle exercise (e.g., walking to work). Mood symptoms were measured with the State-Trait Anxiety Inventory (STAI), the POMS, and the Depression Adjective Checklist (DACL). Mondin and colleagues found that mood disturbance increased over the exercise cessation phase and subsequently decreased when exercise was resumed. This pattern was found for the total mood disturbance, vigor, depression, and tension subscales of the POMS, the STAI, and the DACL. Similarly, scores on the confusion subscale of the POMS increased over the course of the study and then decreased on day 5, when exercise was resumed. Based on their results and their study design involving assessment on a daily basis, the authors concluded that the resulting mood disturbance from exercise withdrawal occurs in as little as 48 hours. Strengths of this study include the experimental design and use of well-validated scales, whereas limitations include the short duration of the exercise withdrawal phase and small sample size. Another study utilizing a 3-day exercise withdrawal period with a physically active female sample, supports this finding, with results indicating an increased mood disturbance and body dissatisfaction over the course of the study (Niven, Rendell, & Chisholm, 2008). An additional study using only a 24-hour exercise cessation protocol with regular runners found changes in self-reported tension, depression, anger, fatigue, confusion and vigor over this 1-day period, with a moderating effect of addiction to running (Aidman & Woollard, 2003). This study suggests that the severity of certain mood symptoms following exercise withdrawal is higher among individuals with greater levels of self-reported exercise addiction, whereas other symptoms (e.g., fatigue, reduced vigor) are endorsed at similar levels by all individuals who cease their exercise for a 24-hour period, with authors suggesting further research to confirm these results.

Glass and colleagues (2004) conducted a study with a longer exercise withdrawal phase than was used by Mondin and colleagues (1996). In this design, 18 participants who engaged in aerobic exercise for at least 4 hours per week were required to refrain from physical activity for a 1-week period. Participants were assessed prior to and after the exercise withdrawal phase on a variety of constructs: pain (McGill Pain Questionnaire), fatigue (Multidimensional Fatigue Inventory), and mood (Beck Depression Inventory and State-Trait Anxiety Inventory). Additionally, autonomic (i.e., heart rate variability), immune (i.e., NK cell activity), and HPA axis functioning (i.e., cortisol and adrenocorticotropic hormone levels) was measured. Approximately 50% of participants developed psychological symptoms over the course of the study, with pain as the most common symptom, followed by fatigue and mood disturbance. The authors suggested that anticipatory effects of returning to exercise at the second time point (participants completed measures at the end of the 7^{th} day) may have diminished mood effects. Additionally, it was concluded that lower initial autonomic nervous system (i.e., heart rate variability), immune (i.e., NK cell responsiveness), and HPA axis functioning (i.e., cortisol and adrenocorticotropic hormone levels) was associated with greater subsequent pain, fatigue or mood disturbance following exercise withdrawal. These findings suggest a biological vulnerability to the development of mood disturbance following exercise withdrawal. Strengths of this study include the experimental design, an extended duration of the exercise cessation period, the incorporation of biological measures, and the use of well-validated scales. Limitations to the study include a small sample size and the timing of the second assessment, as previously described. Additional studies utilizing an exercise withdrawal period of 7 days found that exercise cessation was predictive of mood disturbance (Szabo & Parkin, 2001), as well as physical symptoms (e.g., headache, stomach pain, chest pain, sore throat; Gauvin & Szabo, 1992).

Berlin and colleagues (2006) used a longitudinal experimental design in which 40 habitual exercisers, defined as individuals who engaged in aerobic exercise for at least 30 minutes, three times per week, were randomized to one of two conditions for 2 weeks: maintained exercise or aerobic exercise withdrawal. This study was designed to examine the effects of exercise withdrawal on depressive symptoms and fatigue, as well as the contribution of reduced cardiovascular fitness to exercise withdrawal-related mood changes. Participants were assessed with the POMS, Beck Depression Inventory-Second Edition (BDI-II), and Multidimensional Fatigue Inventory (MFI) and underwent exercise testing to determine VO_2 peak at baseline, 7 days, and 14 days into the protocol.

Consistent with previous literature, the exercise withdrawal group reported significantly greater depressive symptoms measured by both the POMS and the BDI-II compared to the control group at the 2-week time point. In addition, the groups differed on the fatigue, tension, and vigor subscales of the POMS at 2 weeks. Interestingly, an increase in somatic symptoms (at day 7) was found to precede the onset of cognitive symptoms (at day 14) on the BDI-II. Contrary to their hypothesis, the exercise withdrawal group did not show a significant decrease in fitness level over the course of the withdrawal period; however, the subset of individuals in the exercise withdrawal group who displayed a decrease in fitness level developed greater depressive symptoms relative to those who did not experience a reduction in fitness, suggesting a contribution of decreased fitness level to mood disturbance over exercise cessation. This study is one of the first to examine the effects of exercise withdrawal on mood disturbances in an experimental longitudinal design and the only study to consider the possible role of change in cardiovascular fitness levels. Strengths of this study include the use of well-validated psychological measures, a sound experimental design, adherence to the protocol measured via ambulatory accelerometer data, and an exercise withdrawal period of 2 weeks. A limitation of the study is the less stringent physical activity criteria used for inclusion, as current guidelines recommend a minimum of 30 minutes of moderate-intensity aerobic physical activity 5 days per week or 20 minutes of vigorous-intensity aerobic physical activity 3 days per week to derive general health benefits (Haskell et al., 2007). Subsequent analyses examined the role of inflammatory markers in exercise cessation and mood symptoms, with results indicating that these biological markers did not appear to be associated with the increase in mood symptoms and fatigue reported in the exercise cessation group (Kop, Weinstein, Deuster, Whittaker, & Tracy, 2008). In another study with a similar protocol, participants were randomized to 2 weeks of exercise cessation or continued exercise. In this study, exercise cessation was found to be associated with increased overall mood disturbance, with a moderating effect of sex, such that females reported a more detrimental effect relative to men (Poole, Hamer, Wawrzyniak, & Steptoe, 2011). Contrary to the lack of findings regarding inflammatory responses in exercise cessation previously reported, these authors found a modest reduction in the inflammatory marker interleukin-6 (IL-6), which was associated with the reported increase in mood symptoms. A further study found a significant increase in expected mood disturbance to an imaginal 2-week period of exercise cessation relative to an imaginal neutral situation (Guszkowska & Rudnicki, 2012).

A novel study conducted by Hausenblas, Gauvin, Symons Downs, and Duley (2008) utilized ecological momentary assessment of mood in a design involving exercise cessation for 3 days. Forty participants were monitored for a 6-day period and given a pager to communicate to the participant each morning whether or not they were allowed to exercise that day. Participants were told that their exercise allocation was determined at random, however, in reality, each participant was required to refrain from exercise on 3 of these 6 days. At four times during the day, participants were paged and asked to indicate their current activity and to fill out the Exercise-Induced Feeling Inventory (EFI; Gauvin & Rejeski, 1993), a 12-item measure assessing affective states associated with exercise: physical exhaustion, positive engagement, revitalization, and tranquility. Additionally, prior to and post-exercise, participants filled out the EFI. Prior to the start of the study, participants were asked to report on which of the upcoming 6 days they were planning to exercise, allowing the authors to compare exercise vs. exercise cessation vs. non-exercise (i.e., the participant was instructed not to exercise, but did not plan on exercising anyways) days. After controlling for diurnal variation in mood, acute exercise was associated with significantly higher positive engagement, revitalization, and tranquility. Interestingly, positive engagement and revitalization were higher on exercise cessation days than on non-exercise days. The authors concluded that exercise withdrawal may not have an effect on positive feeling states, but instead may manifest as negative affect symptoms (e.g., depression, anxiety), which were not assessed with the EFI. Strengths of this study include the experimental design and the use of real-time data collection with multiple assessments throughout the day to examine the relationship between exercise cessation and psychological well-being. Limitations of the study include a small sample size, threats to data validity due to possible non-compliance by participants in completing the questionnaires upon being paged and fully engaging in the exercise withdrawal protocol.

Additional studies have examined mood disturbance following exercise cessation in individuals characterized as high on exercise dependence and found a similar pattern of results (Aidman & Woollard, 2003; Sachs & Pargman, 1979). Although these findings do not generalize to the population of interest in the current study, they are indicative of the overall effects of exercise withdrawal on subsequent mood disturbance, as has been documented in the correlational studies and experimental designs reviewed above.

1.4. Cognitive Vulnerability

Despite research on the effects of exercise cessation on mood symptomatology, no prior study has examined the effects of cognitive vulnerability and its interaction with exercise withdrawal in the prediction of subsequent mood disturbance. However, research on unipolar depression has examined cognitive constructs in the prediction of depressive symptoms. This research has focused on the depressive cognitive vulnerability constructs proposed by Beck's cognitive theory (1967, 1976), involving dysfunctional attitudes and cognitive reactivity (Segal et al., 1999; 2006), and by Nolen-Hoeksema's response styles theory (1991), involving rumination. The subsequent sections will review the theoretical and empirical literature on the association between these cognitive vulnerability constructs and depressive symptoms. The current study draws upon this field of literature, as these associations have not yet been tested in an exercise withdrawal paradigm.

1.4.1. Dysfunctional Attitudes

Beck's cognitive theory for depression proposes three levels of thinking that are involved in the onset and maintenance of depression: core beliefs or schema, intermediate cognitions (i.e., attitudes, rules, and assumptions), and automatic thoughts (Beck, 1967; Beck, Rush, Shaw, & Emery, 1979). Beck's model is a diathesis-stress model in which the interaction of a cognitive vulnerability to depression and the experience of negative life events results in depressive episodes.

Core beliefs or schema are considered the underlying cognitive structures that process information in everyday life, described as "the basic structural components of cognitive organization through which humans come to identify, interpret, categorize, and evaluate their experiences," (Schmidt et al., 1999). Schemas are believed to be formed through experiences in childhood and remain latent until activated later in life. Maladaptive schemas, containing negative core beliefs (e.g., I am unlovable, I am helpless) are considered to be the underlying cognitive vulnerability to depression.

Schemas are important in the formation of intermediate attitudes, rules or assumptions that give rise to automatic thoughts, spontaneous thoughts in conscious awareness. Attitudes are in the form of if-then statements. In depression, these attitudes are dysfunctional (e.g., If I work hard enough to meet my standards, then I am a worthwhile person), such that personal rules or strategies have been formed to cope with maladaptive core beliefs (e.g., I am worthless). In turn, negative life events that interfere with meeting these conditional rules serve to trigger the onset or maintenance of depressive episodes. Dysfunctional attitudes are the most commonly assessed explicit cognitive vulnerability construct based on Beck's model and are measured with the Dysfunctional Attitudes Scale (DAS; Weissman & Beck, 1978).

Longitudinal studies have supported Beck's cognitive theory for depression in that cognitive vulnerability (i.e., dysfunctional attitudes) is associated with a growth in depressive symptoms over time and predictive of depressive episode onset. A study conducted by Alloy and colleagues (2000) examined cognitive patterns in non-depressed individuals as a vulnerability to depression. At baseline, participants were categorized as either high or low cognitive risk based on responses on the DAS and Cognitive Style Questionnaire (CSQ) and were assessed for lifetime prevalence of MDD. Individuals who were categorized as high risk (i.e., scored in the highest quartile on the DAS and composite attributional style for negative events on the CSQ) were three times more likely to have had a major depressive episode over their lifetime compared to those categorized as low risk (i.e., scored in the lowest quartile on the DAS and composite for negative events on the CSQ in cognitive risk). A follow-up study examined whether a negative inferential style and presence of dysfunctional attitudes increases one's risk for future depressive episodes in a prospective longitudinal design (Alloy et al., 2006). In this study, 346 non-depressed participants were categorized as high or low cognitive risk for depression and were then assessed for depressive symptoms every 6 weeks over the course of 2.5 years. Non-depressed individuals who exhibited a negative inferential style and dysfunctional attitudes (i.e., high cognitive risk) were significantly more likely to experience first onsets of major depression, minor depression, and hopelessness depression compared to individuals who did not hold these negative cognitive styles (i.e., low cognitive risk) at baseline. Secondary analyses from this study indicated that the high cognitive risk profile was predictive of more frequent episodes of depression, more severe symptoms, and a more chronic course compared to individuals at low cognitive risk for depression (Iacoviello, Alloy, Abramson, Whitehouse, & Hogan, 2006).

Additional studies have found that the interaction between dysfunctional attitudes and a stressful life event predicts subsequent depression, in support of the diathesis-stress model proposed by Beck (Alloy et al., 2006; Dykman & Johll, 1998; Hankin et al., 2004; Kwon & Oei, 1992; Lewinsohn et al., 2001). For instance, in a study conducted by Hankin and colleagues (2004), college undergraduates were assessed for cognitive vulnerability and then followed up at 5 weeks and 2 years later. Negative life events interacted with dysfunctional attitudes to predict an increase in depressive symptoms at both of these follow-up time points. Additionally, strong dysfunctional attitudes combined with the experience of negative life events was shown to predict the occurrence of major depressive disorder over the 2-year follow-up. Similar studies support the interaction of dysfunctional attitudes with a discrete stressor to predict subsequent depressive symptoms (Brown, Hammen, Craske, & Wickens, 1995; Joiner, Metalsky, Lew, & Klocek, 1999). The current study serves to test this diathesis-stress model where exercise cessation is considered analogous to a personal stressor for individuals who are regular exercisers.

1.4.2. Cognitive Reactivity

The construct of cognitive reactivity is assessed via examining change in dysfunctional attitudes from before to after a dysphoric mood induction, a protocol based on Beck's cognitive model for depression (Beck 1967; 1976). As Beck's theory posits that underlying cognitive constructs remain dormant until activated during times of stress, the cognitive reactivity protocol was developed to examine dysfunctional attitudes when primed with negative affect, thought to be parallel to thoughts activated during real-life shifts in mood in response to stress. The diathesis-stress aspect of Beck's theory implies that the underlying negative cognitive schema require a stressor (i.e., dysphoric mood induction) to become apparent in experimental settings. Consequently, if a participant were to respond to this experimental manipulation with negative thinking, then it is believed that the individual would be more likely to respond with negative thinking to stressor-induced mood changes in real-life, thereby increasing risk for the onset and maintenance of depression.

Research on unipolar depression has found that cognitive reactivity is predictive of depressive episodes in longitudinal studies (Segal et al., 1999; 2006). These studies, which are very relevant to the current project, followed formerly depressed patients treated to remission with either pharmacotherapy or cognitive therapy over the course of one to four years. Participants completed the Dysfunctional Attitudes Scale before and after a dysphoric mood induction with the difference in DAS scores representing a measure of cognitive reactivity. Cognitive reactivity was predictive of depressive episode recurrences over the follow-up period (13-48 months in the first study, $M = 32$; 18 months in the second study), regardless of initial treatment group. This suggests that among formerly depressed individuals in remission, those who respond to a negative mood induction with increased dysfunctional attitudes are at an increased risk for the development of future depressive episodes, implicating the importance of cognitive reactivity as a vulnerability factor for recurrence. There are no studies testing whether cognitive reactivity predicts depressive symptoms or first episodes in individuals without a history of depression. The current study proposes to examine whether cognitive reactivity is associated with mood disturbance in both never- and formerly-depressed individuals in an exercise withdrawal paradigm.

1.4.3. Rumination

Another cognitive model for depression, the response styles theory (Nolen-Hoeksema, 1987, 1991), proposes that rumination, a tendency to repetitively focus on one's symptoms of distress and their causes and consequences, acts as a cognitive vulnerability to depression. Nolen-Hoeksema's theory posits that rumination exacerbates depressed mood by impacting one's current thinking, interfering with problem-solving processes and with instrumental behavior that would otherwise alleviate negative mood.

Ruminative response style appears trait-like, in that it remains stable in individuals over time, regardless of the current level of depressed mood (Bagby, Rector, Bacchiochi, & McBride, 2004; Just & Alloy, 1997; Kuehner & Weber, 1999; Nolen-Hoeksema, Morrow, & Fredrickson, 1993; Nolen-Hoeksema et al., 1994, Watkins, 2009). The cognitive construct of rumination is implicated in the onset and maintenance of depressive symptoms in longitudinal studies of depressed individuals (for review see Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). As reviewed below, research in unipolar depression suggests that rumination is important in the development and maintenance of depressive symptoms and episodes.

Numerous longitudinal studies indicate that a ruminative response style is predictive of depressive symptoms over time (Nolan, Roberts, & Gotlib, 1998; Nolen-Hoeksema & Davis, 1999; Nolen-Hoeksema, Larson, & Grayson, 1999; Nolen-Hoeksema & Morrow, 1991; Nolen-Hoeksema et al., 1994; Sarin et al., 2005; Wood et al., 1990). For instance, a study conducted by Sarin and colleagues (2005) followed 87 college students over the experience of a stressful event (i.e., a difficult exam). Participants were assessed for tendency to ruminate at time point 1 (before the exam) and assessed for depressive and anxiety symptoms immediately following the exam (time point 2), 4-8 hours later (time point 3), and 4 days later (time point 4). Regardless of how participants performed on the exam, tendency to ruminate in response to a depressed mood was associated with greater anxiety and depressive symptoms over the subsequent 4 days.

In addition to its association with increased depressive symptoms, a ruminative response style is also predictive of a greater likelihood of developing a major depressive episode (Just & Alloy, 1997). In this study, 189 participants were assessed for response style and followed for 18 months. Results indicated that higher levels of self-reported trait rumination were associated with a greater risk of developing a depressive episode. Another study found similar results using a longitudinal design over 2.5 years, in which rumination mediated the relationship between negative cognitive styles and depressive episodes (Spasojevic & Alloy, 2001). Additionally, Nolen-Hoeksema (2000) found ruminative response style to be predictive of a future diagnosis of Major Depressive Disorder, assessed over the subsequent year.

Rumination has also been studied in relation to the severity and duration of depressive symptoms. In a study conducted by Just and Alloy (1997), rumination measured when participants were not depressed was predictive of the severity of depressive symptoms present during an initial depressive episode over a follow-up period of 18 months, and this remained significant when controlling for state rumination. Nolen-Hoeksema and colleagues (1993) examined ruminative and distracting response styles in relation to the duration of episodes of depressed mood. In this study, 79 individuals tracked their naturally occurring emotions (i.e., if they had felt sad or depressed) and answered questions regarding their response style to any sad mood experienced on a daily basis for a 30-day period. In examining the association between response style and the total episode duration, individuals who tended to ruminate in response to their depressed mood experienced significantly longer periods of time feeling depressed, a finding supported by additional literature (Nolen-Hoeksema & Morrow, 1991).

Rumination has been measured in the recent unipolar depression literature with the Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991). In a factor analysis, Treynor, Gonzalez, and Nolen-Hoeksema (2003) concluded that rumination is composed of two components, which differentially relate to depression: reflective pondering and brooding, results that have been replicated in different samples (Schoofs, Hermans, & Raes, 2010). Reflective pondering refers to turning inwards to problem-solve in response to depressive symptoms, whereas brooding is defined as a passive state during which one compares his/her life to an unrealistic standard. Reflective pondering has been found to lead to increased negative affect in the short-term, but over longer periods of time has been associated with a reduction in negative affect, perhaps because it promotes problem-solving. Conversely, brooding, in both the short- and long-term has been associated with increased negative affect, and is therefore considered to be the more maladaptive factor (Treynor et al., 2003).

In a study with 116 depressed patients, brooding was associated with both depressive and anxiety symptoms, measured via the BDI-II and BAI, whereas reflective pondering was only associated with anxiety symptoms (Watkins, 2009). Furthermore, in this sample, brooding was related to an increased likelihood of a comorbid diagnosis (specifically generalized anxiety disorder or obsessive-compulsive disorder), whereas reflective pondering did not have the same associations. This study supports distinct subtypes of rumination, with brooding, specifically, associated with psychopathology. Moreover, a meta-analysis by Olatunji, Naragon-Gainey, and Wolitzky-Taylor (2013) examined the association between rumination and anxiety and depressive symptoms. These authors reviewed 179 correlational studies assessing rumination and depression or anxiety symptoms, and 37 studies assessing rumination in clinical samples (i.e., patients met diagnostic criteria for a mood disorder or anxiety disorder) vs. comparison groups. These authors found an overall moderate correlation between rumination and depressive and anxiety symptoms in the correlational designs, with a stronger association observed for brooding, and a weaker association for reflective pondering. Furthermore, results indicated significantly higher levels of rumination, including brooding rumination specifically, among clinical (i.e., mood and anxiety disorders) vs. non-clinical samples.

Although both the brooding and reflective pondering subscales of rumination are examined as a cognitive vulnerability to depression in the current study, based on these results, brooding, specifically, is hypothesized as a diathesis interacting with the stressor of exercise cessation to contribute to mood deterioration in physically active adults.

1.5. Potential Implications of the Proposed Study

The current study adds to the existing literature on the development of mood disturbances in response to exercise withdrawal through the incorporation of cognitive vulnerability constructs, which have been well established as risk factors for unipolar depression onset and recurrence. Thus, this study extends previous work by examining potential mechanisms and moderators that underlie the relationship between mood disturbance and exercise withdrawal.

This study is the first to examine the interactive effects of cognitive vulnerability and exercise withdrawal in the onset of depressive and anxiety symptoms. With the use of a repeated-measures, longitudinal design, cognitive vulnerability factors are examined after a period of maintained physical activity and used as predictors of the development of subsequent depressive and anxiety symptoms during two weeks of exercise withdrawal. More specifically, dysfunctional attitudes, cognitive reactivity, and brooding rumination are examined as potential mechanisms that help explain the onset of mood disturbance following exercise cessation. In addition, potential psychological (i.e., motivation for exercising, general coping style, perspective on the impact of fatigue on one’s life, emotion dysregulation, and perceived personal benefits of exercise) and exercise science (i.e., baseline physical activity) moderators are examined to determine whether these constructs interact with high cognitive vulnerability to predict subsequent mood symptomatology.

This work helps to identify individuals and populations at risk for mood disturbances in response to exercise cessation during developmental transitions, injury, medical conditions, pregnancy, and lifestyle changes. Given both the high prevalence of depression and the high likelihood of experiencing a transitional period involving change in physical activity level over the course of one's lifetime, such work has implications that will generalize across a broad range of populations and situations. The current study is a first step towards identifying individuals at risk for mood symptoms under conditions of reduced physical activity on the basis of established cognitive vulnerability constructs. This work has clinical implications for improved patient assessment, and may inform efficacious treatment strategies, as well as prevention efforts when exercise cessation is foreseen beforehand. Additionally, this work has theoretical implications for understanding the onset and recurrence of depression as it relates to the vulnerability-stress model for depression.

1.6. Study Aims and Hypotheses

The current study aims to identify potential mechanisms and moderators that may explain vulnerability to mood symptomatology when undergoing exercise cessation.

1.6.1. Primary Aims and Hypotheses

1.6.1.1. Aim 1

To replicate and extend past findings on the development of mood disturbance following exercise cessation in physically active adults.

1.6.1.2. Hypothesis 1

Consistent with past findings (e.g., Berlin et al., 2006; Mondin et al., 2006; Glass et al., 2004), greater depressive and anxiety symptoms will be reported during the exercise withdrawal phase relative to the maintained exercise phase across participants.

1.6.1.3. Aim 2

To test cognitive vulnerability constructs (following the maintained exercise phase) as predictors of mood disturbances during the exercise withdrawal phase.

1.6.1.4. Hypothesis 2

Greater cognitive reactivity in response to a dysphoric mood induction, more rigid dysfunctional attitudes, and a greater likelihood of engaging in brooding rumination at the conclusion of the maintained exercise phase will be predictive of greater mood disturbances (i.e., increased depressive and anxiety symptoms) during the 2 weeks of exercise cessation.

1.6.2. Secondary Aims and Hypotheses

1.6.2.1. Aim 3

To examine the role of psychological self-report variables as potential moderators of the relationship between baseline cognitive vulnerabilities and mood disturbance following exercise cessation. The following moderators were examined: motivation for exercise (Reasons for Exercise Inventory), exercise-related coping style (Coping Inventory for Stressful Situations), perspective on the impact of fatigue on one's life (Fatigue Severity Scale), emotion dysregulation (Difficulties in Emotion Regulation Scale), and perceived personal benefits of exercise (Exercise Beliefs Questionnaire).

1.6.2.2. Aim 3a

To examine the main effects of psychological self-report variables, above and beyond the cognitive vulnerability variables, in prediction of mood outcome measures.

1.6.2.3. Hypothesis 3

Psychological self-report measures (i.e., endorsing the mood management benefits of physical activity as one's main motivation for exercise, a greater tendency to exercise to cope with stress, greater perceived impairment associated with fatigue, greater emotional dysregulation, and stronger beliefs regarding the impact of exercise on mental and emotional functioning) will be predictive of mood disturbance over time, with cognitive vulnerability covariates included in the model.

1.6.2.4. Aim 3b

To examine the interactive effects of cognitive vulnerability variables and psychological self-report measures in prediction of mood outcome measures.

1.6.2.5. Hypothesis 4

The interactions of cognitive vulnerability variables and each psychological self-report moderating variable will be predictive of mood disturbance over the course of the study, above and beyond the main effects of the variables included in the model. Specifically, higher cognitive vulnerability is expected to interact with each of the following to predict a greater increase in mood disturbance during the exercise cessation phase: endorsing the mood management benefits of physical activity as one's main motivation for exercise, a greater tendency to exercise to cope with stress, greater perceived impairment associated with fatigue, greater emotional dysregulation, and stronger beliefs regarding the impact of exercise on mental and emotional functioning.

1.6.2.6. Aim 4

To examine the role of baseline physical activity level as a potential moderator of the relationship between cognitive vulnerabilities and mood disturbance following exercise cessation. Baseline physical activity level was calculated as mean energy expenditure per week (MET h-wk) and derived from the Aerobics Center Longitudinal Study Physical Activity Questionnaire (ACLS PAQ) administered at baseline (study visit 1).

1.6.2.7. Aim 4a

To examine the main effect of baseline physical activity level, above and beyond the cognitive vulnerability measures, in prediction of mood outcome measures.

1.6.2.8. Hypothesis 5

Baseline physical activity level will be predictive of mood disturbance over time, with cognitive vulnerability covariates included in the model.

1.6.2.9. Aim 4b

To examine the interactive effect of cognitive vulnerability variables and baseline physical activity level in prediction of mood outcome measures.

1.6.2.10. Hypothesis 6

The interactions of cognitive vulnerability measures and baseline physical activity level will be predictive of mood disturbance over the course of the study, above and beyond the main effects of the variables included in the model. Specifically, participants with a higher cognitive vulnerability to depression who have a greater baseline physical activity level will experience a greater increase in depression and anxiety symptoms over the exercise cessation protocol.

CHAPTER 2: METHODS

2.1. Participants

Participants in this study were 36 physically active adult community residents of the greater Burlington, Vermont area. To be eligible for the study, participants were required to: a) be between the ages of 18 and 64 years; b) meet the 2008 American College of Sports Medicine (ACSM) guidelines for physical activity (Haskell et al., 2007) defined as a minimum of 30 minutes of moderate-intensity aerobic physical activity 5 days per week, or 20 minutes of vigorous-intensity aerobic physical activity 3 days per week; and c) report no contraindications to exercise on the Physical Activity Readiness Questionnaire (PAR-Q; i.e., no positive responses). Individuals were excluded from the study based on a) a current Major Depressive Episode as assessed by the Structured Clinical Interview for DSM-IV Axis I Disorders-Clinician Version (SCID-CV; First, Spitzer, Gibbon, & Williams, 1995); b) acute and serious suicidal intent; c) current Axis I disorder requiring immediate treatment (e.g., mania, hypomania, substance dependence, acute psychosis); d) deemed as exercise dependent (i.e., ratings of 5-6 on three of the seven criteria for exercise dependence) on the Exercise Dependence Scale (EDS; Hausenblas & Symons Downs, 2002); e) plans of vacation, periods of absence, or change in physical activity routine during the upcoming 6 weeks; f) use of antidepressant medications; and g) participation in a high-school, university, or semi-professional athletic team. Current mental health diagnosis was generally allowed in the study with the exception of those conditions specified in a-c. Major Depression was excluded because it is ethically problematic to have clinically depressed individuals undergo a dysphoric mood induction such as the procedure in the cognitive reactivity protocol. Individuals endorsing suicidal intent and/or meeting criteria for a mental illness requiring immediate treatment were excluded as their severity deems them not appropriate for study participation. Individuals considered to be exercise dependent were excluded from the study because prior studies have shown that this subset of individuals has difficulty following exercise cessation protocols and is unlikely to participate in exercise withdrawal studies (Hausenblas et al., 2008; Sazbo, 1995).

2.2. Recruitment and Compensation

Physically active adults between the ages of 18 and 64 were recruited from a) advertisements in community boards and internet websites, b) campus-wide announcements, and c) undergraduate psychology classes at the University of Vermont. Given that the informed consent provides a brief summary about exercise cessation literature, advertisements were transparent regarding variables being assessed (i.e., mood measures). Advertisements indicated that regular exercisers were being recruited and that individuals would be asked to refrain from exercising for a 2-week period of time.

Individuals who responded to advertisements underwent a brief phone screen to determine potential study eligibility. Prior to study consent, the phone screen gathered information in order to preliminarily assess the following inclusion/exclusion criteria: current physical activity level, medical contraindications to exercise, and diagnostic criteria for a current Major Depressive Episode. Based on the phone screen, potentially eligible individuals were invited to the in-person screening visit.

Eligible community participants received a total of $80 for completion of the study. To reduce attrition, participants were compensated after the completion of each study visit: $10 after study visit 1, $30 after study visit 2, and $30 after study visit 3, plus

$10 for completion of mail-in questionnaire measures completed 1-week into exercise cessation phase. Participants were only compensated for study visit 1 if they met eligibility criteria and completed the study visit. Undergraduate psychology students were offered extra credit points in courses that they are enrolled in for their participation in this study, based on agreements with course instructors regarding the amount of points that were equivalent to study completion. Additionally, participants were provided with individualized information at study visit 3 regarding the trajectory of their symptom onset and the types of symptoms that were prominent (e.g., depressive vs. anxiety, somatic vs. cognitive symptoms). This information benefits participants as it provides them with insight into their pattern of symptoms in the development of mood disturbances upon exercise cessation, which is important in terms of awareness for future mood problems.

2.3. Measures

See the table below for a summary of the measures administered over the course of the study. A description of each measure is provided in the next section.

Table 1: Measures Administered over the Course of the Study

	Study visit 1	Study visit 2	Study visit 3	Mail-in questionnaires
Physical Activity Readiness Questionnaire (PAR-Q)	X			
Exercise Dependence Scale	X			
Aerobics Center Longitudinal Study Physical Activity Questionnaire (ACLS PAQ)	X			
Structured Clinical Interview for DSM-IV Axis I Disorders-Clinician Version (SCID-CV)	X			
Demographic Form	X			
Beck Depression Inventory – 2nd Edition (BDI-II)	X	X	X	X
Beck Anxiety Inventory (BAI)	X	X	X	X
Profile of Mood States – Brief	X	X	X	X

Version (POMS Brief)				
Dysfunctional Attitudes Scale – Form A and Form B (DAS)		X		
Ruminative Responses Scale (RRS)		X		
Difficulties in Emotion Regulation Scale (DERS)		X		
Fatigue Severity Scale (FSS)		X		
Reasons for Exercising Inventory (REI)		X		
Exercise Beliefs Questionnaire (EBQ)		X		
Coping Inventory for Stressful Situations (CISS)		X		

2.3.1. Screening and Diagnostic Assessment

2.3.1.1. Physical Activity Readiness Questionnaire (PAR-Q)

The PAR-Q is a seven-item self-report measure used to assess safety of engagement in physical activity (Thomas, Reading, & Shephard, 1992). This measure identifies individuals who require medical evaluation prior to exercise testing and is recommended for usage by the American College of Sports Medicine (American College of Sports Medicine, 1991; Shephard, 1994). The PAR-Q was administered at study visit 1 with any positive responses endorsed resulting in exclusion from the study.

2.3.1.2. Exercise Dependence Scale (EDS)

The EDS is a 21-item self-report measure used to assess exercise dependence in physically active individuals (Hausenblas & Symons Downs, 2002). This measure has seven subscales consistent with the DSM-IV diagnostic criteria for substance abuse: tolerance, withdrawal, intention effect, lack of control, time, reduction in other activities, and continuance. Individuals who scored high (i.e., scores of 5 or 6) on 3 or more criteria are considered to be at-risk for exercise dependence. The EDS has demonstrated good concurrent validity, internal consistency, and test-retest reliability (Hausenblas & Fallon, 2002; Hausenblas & Symons Downs, 2002; Symons Downs, Hausenblas, & Nigg, 2004). Participants rated exercise beliefs and behaviors over the past 3 months on a 6-point scale from 1 ("Never") to 6 ("Always"). Items include statements such as "I exercise longer than I intend," "I exercise to avoid feeling anxious," and "I exercise when injured." The EDS was administered at study visit 1 to determine eligibility in the study.

2.3.1.3. Aerobics Center Longitudinal Study Physical Activity Questionnaire (ACLS PAQ)

The ACLS PAQ is an instrument used to assess leisure and household physical activity in the past 3 months (Cooper, 1997). It is well validated and strongly correlated with objective measures of physical fitness (Dinger et al., 2000; Kohl et al., 1988; Oliveira et al., 1996). This measure produces a total physical activity score as well as a physical activity score excluding household tasks, stair climbing, and lawn work; the latter was used in this study. These scores are represented as MET-hours per week, or estimates of weekly energy expenditure based on calculations using each reported physical activity and its intensity. The ACLS PAQ was administered at study visit 1. Only participants who met the minimum physical activity guidelines, defined above, continued with the study. The calculated estimated weekly energy expenditure (MET-hours per week) was used as a measure of baseline physical activity level in statistical analyses.

2.3.1.4. Structured Clinical Interview for DSM-IV Axis I Disorders-Clinician Version (SCID-CV)

The SCID-CV (First et al., 1995) is a structured interview designed to assist in making the major Axis I diagnoses identified by the American Psychiatric Association in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition. The SCID-CV was used to assess current mental health diagnoses, to code for a history of Major Depressive Disorder (MDD), and to determine if the participant met any of the exclusionary psychiatric criteria (i.e., Major Depressive Episode, acute and serious suicidal intent, current Axis I disorder requiring immediate treatment). The P.I., who is trained and experienced in using this measure, administered the SCID-CV to potentially eligible participants at study visit 1.

2.3.1.5. Demographic Variables

Participants completed a demographic form at study visit 1. Variables of interest include a) age, b) gender, c) educational level, d) marital status, e) history of involvement in competitive sports, f) current medications, and e) assessment of health-relevant behaviors (e.g., dieting, alcohol and drug intake).

2.3.2. Self-Report Assessments of Cognitive Vulnerability

2.3.2.1. Dysfunctional Attitudes Scale – Form A and Form B (DAS)

The DAS is a self-report measure of conviction in 40 beliefs that are commonly endorsed in depressed individuals (Weismann & Beck, 1978). This measure has shown high internal consistency and test-retest reliability (Dobson & Breiter, 1983; Weissman, 1978). Items include statements such as “If I do not do well all the time, people will not respect me” and “If a person asks for help, it is a sign of weakness.” Participants rated the beliefs on a 7-point Likert scale from 1 (“totally disagree”) to 7 (“totally agree”). Parallel versions of the DAS, Form A and Form B, were utilized in the cognitive reactivity protocol at study visit 2, before and after the mood induction, respectively.

2.3.2.2. Ruminative Responses Scale (RRS)

The RRS is a self-report measure of rumination, one's tendency to repetitively focus on one's symptoms of distress and the causes and consequences of these symptoms (Nolen-Hoeksema & Morrow, 1991). This 22-item measure assesses responses to sad mood on a 4-point Likert scale from 1 ("Almost never respond in this way") to 4 ("Almost always respond in this way") with three factor analytically derived subscales: depression, brooding, and reflective-pondering. The brooding rumination subscale of the RRS was used in the statistical analyses in this study. Items comprising this subscale include statements such as "Think 'What am I doing to deserve this?'" and "Think 'Why can't I handle things better?'" The RRS has shown good concurrent validity, test-retest reliability, and internal consistency (Nolen-Hoeksema et al., 2008). This measure was administered at study visit 2.

2.3.3. Experimentally-Assessed Cognitive Vulnerability

2.3.3.1. Cognitive Reactivity

Cognitive reactivity is measured as the change in scores on the Dysfunctional Attitudes Scale (DAS) from before to after a dysphoric mood induction (See Negative Mood Induction Procedure, below). Cognitive vulnerability to depression research has shown greater cognitive reactivity in formerly depressed patients relative to never-depressed controls (Gemar, Segl, Sagrati, & Kennedy, 2001). Cognitive reactivity measured this way is a strong and significant predictor of future depressive episodes among formerly depressed individuals who recovered in treatment (Segal et al., 1999).

To reduce possible demand characteristics associated with this procedure, participants were told that the task is designed to examine the relationship between emotions and memories. At study visit 2, DAS – Form A was administered prior to and DAS – Form B was administered after the dysphoric mood induction, described under Procedures, to measure cognitive reactivity. The rationale behind conducting this procedure during the second visit rather than the first, was to prevent unnecessary administration for individuals who did not meet the physical activity guidelines set by the American College of Sports Medicine after the "run-in weeks" (i.e., their daily exercise diary turned in at Laboratory Visit 2 indicates that their physical activity level is below the necessary threshold).

2.3.3.2. Visual Analogue Scale (VAS)

Consistent with past studies (Gemar, Segal, Sagrati, & Kennedy, 2001; Segal et al., 1999), participants were asked to rate their current mood immediately before and after the dysphoric mood induction at study visit 2 to test whether the manipulation was successful in experimentally-inducing a sad mood. Participants indicated on a visual analogue scale (VAS) their current subjective mood state by drawing a vertical mark along a 150-mm line with the anchors of "happy" and "sad" on each end.

2.3.4. Potential Psychological Moderating Variables

2.3.4.1. Difficulties in Emotion Regulation Scale (DERS)

The DERS is a 36-item self-report measure used to assess multiple aspects of emotion dysregulation (Gratz & Roemer, 2004). The measure yields a total score and six subscales: 1) non-acceptance of emotional responses, 2) difficulties in engaging in goal-directed behavior, 3) impulse control difficulties, 4) lack of emotional awareness, 5) limited access to emotion regulation strategies, and 6) lack of emotional clarity. The total score from this measure was used in the current study. Items include "I have no idea how I'm feeling" and "When I'm upset, I have difficulty concentrating on other things," and are rated on a 5-point Likert scale from 1 ("Almost never") to 5 ("Almost always"). Findings have shown the DERS has high internal consistency, good test-retest reliability, and adequate construct and predictive validity (Gratz & Roemer, 2004). The DERS was administered at study visit 2.

2.3.4.2. Fatigue Severity Scale (FSS)

The FSS is a 9-item self-report measure used to assess a participant's perspective on how fatigue affects one's life (Krupp, LaRocca, Mui-Nash, & Steinberg, 1989). Participants rated their agreement with each statement on a 7-point Likert scale from 1 ("Strongly disagree") to 7 ("Strongly agree"). Items include "My motivation is lower when I'm fatigued" and "Fatigue interferes with my work, family or social life." The FSS has good test-retest reliability and construct validity (Krupp et al., 1989). The FSS was administered at study visit 2.

2.3.4.3. Reasons for Exercising Inventory (REI)

The REI is a 24-item self-report measure used to assess four motivational domains for exercising: appearance/weight management, fitness/health management, stress/mood management, and socializing (Cash, Novy, & Grant, 1994; Silberstein, Streigel-Moore, Timko, & Rodin, 1988). The stress/mood management subscale was used in the statistical analyses of the current study. Participants rated items on a 7-point Likert scale from 1 ("Not at all important") to 7 ("Extremely important"). Items of the stress/mood management subscale include “To cope with stress/anxiety” and “To improve my mood.” The REI was administered at study visit 2.

2.3.4.4. Exercise Beliefs Questionnaire (EBQ)

The EBQ is a 21-item self-report measure used to assess assumptions regarding the effects that exercise has on oneself. It has four subscales: social desirability, physical appearance, mental and emotional functioning, and vulnerability to disease and aging (Loumidis & Wells, 1998). Participants were asked to rate their belief in the statements on a scale from 0 (“I do not believe this thought at all”) to 100 (“I am completely convinced this thought is true”). The mental and emotional functioning subscale was used in the statistical analyses in the current study. Items of this subscale include “If I do not exercise, I will not be able to work efficiently” and “If I do not exercise, I will not be able to cope with my emotions.” The EBQ has good test-retest reliability, internal reliability, and concurrent validity (Loumidis & Wells, 1998). This measure was administered at study visit 2.

2.3.4.5. Coping Inventory for Stressful Situations (CISS)

The CISS is a 48-item self-report measure used to assess general coping style. Participants rate on a 5-point Likert scale from 1 (“Not at all”) to 5 (“Very much”) how often they engage in the listed behaviors when faced with a difficult or stressful situation (Endler & Parker, 1990). The CISS has three subscales: task-, emotional-, and avoidance-related coping. The CISS has demonstrated good test-retest reliability, internal consistency and construct validity (Endler & Parker, 1990; 1994; 1999). Thome and Espelage (2004) included three items in the CISS to form an exercise-coping subscale for a study of undergraduate students: “Go to the gym to work out,” “Do something active, such as running," and "Get some exercise," with factor analysis confirming the presence of this fourth exercise-related coping subscale. The CISS, including the items comprising the exercise-related coping subscale, was administered at study visit 2.

2.3.5. Assessment of Mood

2.3.5.1. Beck Depression Inventory–2nd Edition (BDI-II)

The BDI-II is a 21-item self-report measure used to assess cognitive, affective, and physical depressive symptoms (Beck, Steer, & Brown, 1996). Participants were asked to rate each item on a 4-point Likert scale from 0 (not endorsed) to 3 (endorsed at maximum severity). Items include difficulty concentrating, experiencing sadness, and loss of energy. The BDI-II has good test-retest reliability and convergent validity (Beck et al., 1996). Comparisons between the original BDI and the BDI-II indicate that the latter has stronger factorial validity (Dozois, Dobson, & Ahnberg, 1998). This measure was administered at study visits 1, 2, and 3, and included in the mail-in questionnaires completed at 1-week into the exercise cessation phase.

2.3.5.2. Beck Anxiety Inventory (BAI)

The BAI is a 21-item self-report measure used to assess somatic or panic-related anxiety symptoms (Beck, Steer, & Beck, 1993). The BAI has good test-retest reliability and convergent validity (Beck et al., 1988). Each item is rated on its presence in the prior week on a 4-point Likert scale from 0 ("Not at all") to 3 ("Severely; I could barely stand it"). Examples of items include feeling nervous, experiencing numbness or tingling, and being afraid of losing control. This measure was administered at study visits 1, 2, and 3, and included in the mail-in questionnaires completed at 1-week into the exercise cessation phase.

2.3.5.3. Profile of Mood States – Brief Version (POMS Brief)

The POMS Brief is a 30-item self-report measure used to assess both positive and negative mood states (McNair et al., 1971; McNair, Loor, & Droppleman, 1992). It has been used extensively in exercise science and mood state research and has been validated for use in college student populations (Curran, Andrykowski, & Studts, 1995; Berger & Motl, 2000; Leith, 1994). Participants were asked to rate each item (e.g., annoyed, efficient, forgetful) based on how they feel in the moment on a 5-point Likert scale from 0 "Not at all" to 4 "Extremely." Items from the POMS Brief form six subscales of mood states: Tension, Anger, Depression, Vigor, Fatigue, and Confusion. A total score representing overall mood disturbance is calculated from the sum of all items minus the Vigor subscale score. The tension and depression subscale scores were used in the statistical analyses in the current study. This measure has shown to have good internal consistency and test-retest reliability (McNair et al., 1992). The POMS Brief has shown to highly correlate with the original 60-item version (McNair et al., 1992). This measure was administered at study visits 1, 2, and 3, and included in the mail-in questionnaires completed at 1-week into the exercise cessation phase.

2.4. Adherence to Study Protocol

2.4.1. Accelerometer Data

Participants were required to wear wrist-worn ActiGraph wGT3X+ activity monitors (ActiGraph, LLC, Pensacola, FL, USA) for the 4 weeks of the study to determine adherence to the exercise cessation study protocol. The ActiGraph wGT3X+ is a lightweight 3-axis accelerometer that was attached to participants' wrists with a velcro wrist strap. Participants decided which wrist to wear the activity monitor on, and information about positioning on dominant or non-dominant hand was taken into account when initializing the device prior to wear. At study visit 1, participants were fitted with activity monitors to wear over the maintained exercise phase. At study visit 2, data was taken from the activity monitors before they were re-charged and returned to the participants to wear over the subsequent two weeks (i.e., exercise cessation phase). Vector magnitude activity counts for the maintained exercise phase (14 days) and the exercise cessation phase (14 days) were calculated using the Freedson VM3 EE algorithm and the Freedson Adult VM3 cut points with the ActiLife data analysis platform.

CHAPTER 3: PROCEDURES

Approval from the Institutional Review Board at the University of Vermont was obtained prior to any data collection. See the table below for a summary of the study procedures in the order that they occurred at each study visit.

Table 2: Procedures at Each Study Visit

Study Visit 1	Study Visit 2	Study Visit 3
1.) Informed consent	1.) Review exercise log to verify study eligibility	1.) Review adherence to exercise cessation in prior 2 weeks
2.) Diagnostic and inclusion/exclusion criteria procedures a. Physical Activity Readiness Questionnaire b. Exercise Dependence Scale c. Structured Clinical Interview for DSM-IV Axis I Disorders-Clinician Version d. Aerobics Center Longitudinal Study Physical Activity Questionnaire e. Demographics questionnaire Eligible participants are invited to complete the mood measures in (3). For respondents meeting psychiatric exclusion criteria, diagnostic interview is discontinued and referral was provided.	2.) Self-report measures a. Beck Depression Inventory – 2nd Edition b. Beck Anxiety Inventory c. Profile of Mood States – Brief Version d. Ruminative Responses Scale e. Reasons for Exercising Inventory f. Exercise Beliefs Questionnaire g. Coping Inventory for Stressful Situations h. Fatigue Severity Scale i. Difficulties in Emotion Regulation Scale	2.) Self-report measures a. Beck Depression Inventory – 2nd Edition b. Beck Anxiety Inventory c. Profile of Mood States – Brief Version
3.) Self-report measures a. Beck Depression Inventory – 2nd Edition b. Beck Anxiety Inventory c. Profile of Mood States – Brief Version	3.) Dysphoric mood induction procedure a. Dysfunctional Attitudes Scale – Form A b. Visual Analogue Scale c. Participant writes about a sad memory and listens to "Russia Under the Mongolian Yoke" through headphones d. Visual Analogue Scale	3.) All subjects were debriefed and compensated $40 ($30 for laboratory visit + $10 for midpoint self-report measures).

	e. Dysfunctional Attitudes Scale – Form B	
4.) All subjects were compensated $10, given an exercise log to be completed daily for the upcoming 2 weeks, and scheduled for the second study visit.	4.) All subjects were compensated $30, given instructions to cease all aerobic physical activity over upcoming 2 weeks, complete and return mood measures after seven days and scheduled for the third study visit.	

3.1. Screening Visit: Study Visit 1

Individuals who responded to study advertisements underwent a brief phone screen to determine potential study eligibility. Prior to study consent, the phone screen gathered contact information and preliminarily assessed the following inclusion/exclusion criteria: current physical activity level; medical contraindications to exercise; and diagnostic criteria for a current Major Depressive Episode. Based on the phone screen, potentially eligible individuals were invited to the in-person screening visit. At the screening visit, individuals reviewed the informed consent document, and then completed the Physical Activity Readiness Questionnaire (PAR-Q). Any positive responses endorsed on this measure resulted in exclusion from the study. Following, participants completed the Exercise Dependence Scale (EDS), with scores of 5 or 6 on three or more of the seven criteria resulting in exclusion from the study. Subsequently, the Aerobics Center Longitudinal Study Physical Activity Questionnaire (ACLS PAQ) was administered. Individuals who were not eligible based on these assessments were given an explanation of their exclusion and thanked for their time. Next, the Structured Clinical Interview for DSM-IV Axis I Disorders-Clinician Version (SCID-CV) was administered.

If any of the exclusionary psychiatric criteria were met, the individual was informed of his/her ineligibility and provided with a referral list for services in the area.

Eligible individuals completed the demographics form and mood measures (see Measures). Participants were fitted with an activity monitor (see Activity Monitor) to wear over the upcoming maintained exercise and exercise cessation phases (i.e., upcoming 4 weeks) and asked to fill out a daily exercise diary for the following 2 weeks. The daily exercise diary was used to to verify that participants who entered the exercise withdrawal phase met the minimum guidelines for physical activity, based not solely on retrospective recall but on daily reporting of their exercise routines. Data from the activity monitor was used to determine adherence to the exercise cessation protocol. The exercise diary asked participants what physical activity they engaged in, the frequency, duration, and intensity of each exercise, and the amount of enjoyment that they got out of that activity.

Eligible participants who completed the study visit 1 procedures were compensated $10 for their time and scheduled for study visit 2, approximately 2 weeks from that day.

3.2. Study Visit 2

At the start of the visit, data from the activity monitor was collected and the individual's daily exercise log was reviewed to verify that baseline physical activity met the guidelines per the American College of Sports Medicine. Participants were then asked to complete the three questionnaires assessing mood and a battery of psychological self-report questionnaires (see Measures). Cognitive reactivity was determined with the use of a dysphoric mood induction (see Dysphoric Mood Induction Procedure). Prior to the negative mood induction, a VAS scale and the Dysfunctional Attitudes Scale – Form A were administered. Immediately following the mood induction, the participant again completed a VAS scale and the Dysfunctional Attitudes Scale – Form B.

At the end of the study visit 2, participants were given instructions to cease all exercise for the upcoming 2 weeks. They were asked to complete the midpoint mood questionnaires (i.e., BDI-II, BAI, POMS Brief) at one week into the exercise withdrawal phase. These measures were provided to them in a preaddressed stamped envelope, with instructions to complete them on the 7th day after study visit 2, and participants were told to expect a reminder call on this day to complete and return these measures. At the end of the study visit, participants were thanked for their time and compensated $30.

3.2.1. Dysphoric Mood Induction Procedure

To induce a sad mood, participants were instructed to "write down on a piece of paper a memory that makes you sad." Subsequently they were asked to continue thinking of the memory and its associated emotion for a 10-minute period. At the same time, the participant listened to the orchestral introduction to Russia Under the Mongolian Yoke by Prokofiev, recorded at half-speed, through headphones. Research has shown that this procedure is effective in inducing a transient dysphoric mood state that lasts between 10 and 15 minutes (Gemar et al., 2001; Segal et al., 1999).

3.3. Study Visit 3

Upon arriving at the third study visit, participants were asked if they had engaged in exercise over the prior two weeks. If participants responded that they had engaged in exercise for more than one day per week over the previous two weeks, they were excluded from the study. Participants were asked to complete the three questionnaires assessing mood (i.e., BDI-II, BAI, POMS Brief). The MDD module of the SCID-CV was administered about the prior two weeks to assess whether participants met diagnostic criteria for a Major Depressive Episode at the conclusion of the exercise cessation phase. Activity monitors were collected and the participants were debriefed, thanked for their time and compensated $40 ($10 for the mail-in questionnaires and $30 for study visit 3).

3.4. Data Analytic Strategy

Linear mixed model (LMM) analyses were used to analyze between-subject and within-subject effects, in which cognitive vulnerability variables and potential moderators were analyzed as fixed effects. LMM analysis is more sensitive to detecting change than ANOVA or MANOVA approaches (Speer & Greenbaum, 1995); therefore, LMM is well-suited to testing what may be relatively small but important effects of cognitive vulnerability and the potentially moderating variables in the prediction of mood disturbance during exercise cessation in the present study. Analyses were done using all available data. In addition to the analyses presented below, follow-up analyses examined whether significant effects for the primary aims were maintained when covariates (i.e., sex, age, past major depressive episode) were added into the model.

3.4.1. Hypothesis 1: Change in Mood Over Time

It was predicted that across subjects, individuals would experience greater depressive and anxiety symptoms over the exercise cessation phase compared to the maintained physical activity phase. The slope of the unconditional LMM model was utilized to examine the change in mood measures (i.e., BDI-II, BAI, POMS Brief scores) over the course of the study. These analyses were used to assess the overall shape of change in mood disturbance over the course of the study, across all participants.

3.4.2. Hypothesis 2: Cognitive Vulnerability Predicting Mood Disturbance

It was expected that higher levels of cognitive vulnerability measured at study visit 2 would be predictive of greater increases in depressive and anxiety symptoms over the exercise cessation phase. To test this hypothesis, each measure of mood disturbance (i.e., BDI-II, BAI, POMS Brief scores) was modeled as a function of the fixed effects of cognitive vulnerability (i.e., cognitive reactivity, dysfunctional attitudes, and brooding rumination) and the interactive effects of cognitive vulnerability measures by time with nested model comparisons using likelihood ratio tests used to determine the best fitting model. It was expected that mood disturbance would show a linear increase over the course of the study and that this would vary by cognitive vulnerability, such that high levels for each cognitive vulnerability construct would be associated with greater depressive and anxiety symptoms over time. Furthermore, it was expected that cognitive vulnerability would interact with time, such that individuals with higher levels of these cognitive vulnerability constructs would show greater increases (i.e., steeper slopes) across the study protocol relative to those who scored lower on these constructs. Cognitive vulnerability variables were measured via continuous scores to best capture the full range of these constructs, and were grand mean centered prior to analyses. Significant interactions were explored graphically post-hoc.

3.4.3. Hypothesis 3: Psychological Self-Report Measures Predicting Mood Disturbance

It was predicted that the psychological self-report measures (i.e., endorsing the mood management benefits of physical activity as one's main motivation for exercise, greater tendency to exercise to cope with stress, greater perceived impairment associated with fatigue, greater emotional dysregulation, and stronger beliefs regarding the impact of exercise on mental and emotional functioning) would be predictive of mood disturbance over time, with covariates from the primary analyses (i.e., hypotheses 1 and 2) included in the model. To examine this hypothesis, mood measures (i.e., BDI-II, BAI, POMS Brief scores) were modeled as a function of the fixed effects of cognitive vulnerability constructs, psychological self-report measures, and the interactive effects of the psychological self-report measures by time with nested model comparisons using likelihood ratio tests used to determine the best fitting model. It was expected that each psychological self-report measure would be a significant predictor of change in mood disturbance over the course of the study, such that identifying the mood management benefits of physical activity as one's main motivation for exercise, using exercise to primarily cope with stress, greater perceived fatigue-related impairment, greater emotional dysregulation, and/or more strongly endorsing that exercise enhances mental and emotional functioning would be associated with greater depressive and anxiety symptoms over time. Furthermore, it was expected that these psychological self-report measures would interact with time, such that individuals with higher levels of these constructs would show greater increases (i.e., steeper slopes) across the study protocol relative to those who scored lower on these constructs. These psychological self-report measures were examined as continuous scores to best capture the full range of these constructs, and were grand mean centered prior to analyses. The Fatigue Severity Scale and the Difficulties in Emotion Regulation Scale both yield total scores, whereas the relevant subscale scores of the Reasons for Exercise Inventory, Coping Inventory for Stressful Situations, and the Exercise Beliefs Questionnaire were used for the analyses.

3.4.4. Hypothesis 4: Psychological Self-Report Measures as Moderators

It was expected that a high levels of cognitive vulnerability and one or more of the following conditions would be associated with a greater risk for the development of mood symptoms during the exercise cessation phase: mood management benefits of physical activity as one's main motivation for exercise, greater tendency to exercise to cope with stress, greater perceived impairment associated with fatigue, greater emotional dysregulation, or more strongly reporting that exercise improves mental and emotional functioning. To examine this hypothesis, the mood measures (i.e., BDI-II, BAI, POMS Brief scores) were modeled as a function of the fixed effects of the cognitive vulnerability variables, the psychological self-report moderators, and the interaction of these variables, with covariates from the primary analyses (i.e., hypotheses 1 and 2) and covariates from the previous hypothesis included in the model. Cognitive vulnerability by psychological self-report interactions were examined for any covariate included in final models for hypothesis 3. Nested model comparisons using likelihood ratio tests were used to determine the best fitting model, and significant interactions were explored graphically post-hoc. It was expected that the cognitive vulnerability variable by psychological self-report variable interactions would be significant predictors of change in mood disturbance, above and beyond the main effects observed from these variables, such that higher levels of both constructs would be associated with greater increases in depressive and anxiety symptoms over the course of the study. For example, in regards to the cognitive vulnerability construct of dysfunctional attitudes and the psychological self-report measure of emotion dysregulation, it was expected that higher levels of dysfunctional attitudes and greater emotional dysregulation would be associated with increased depressive and anxiety symptoms over the exercise cessation phase relative to lower levels on either of these measures.

3.4.5. Hypothesis 5: Baseline Physical Activity Predicting Mood Disturbance

It was expected that higher levels of baseline physical activity level would be predictive of increased mood disturbance over the course of the study, with covariates from the primary analyses (i.e., hypotheses 1 and 2) included in the model. To test this hypothesis, each measure of mood (BDI-II, BAI, POMS Brief scores) was modeled as a function of the fixed effects of cognitive vulnerability constructs and baseline physical activity level with nested model comparisons using likelihood ratio tests used to determine the best fitting model. It was expected that the linear change in mood disturbance over the course of the study would vary by this exercise science construct, such that higher baseline physical activity levels would be associated with greater depressive and anxiety symptoms over time. Baseline physical activity was examined as a continuous variable to best capture the full range of this construct, and was grand mean centered prior to analyses.

3.4.6. Hypothesis 6: Baseline Physical Activity as a Moderator

It was predicted that the combination of higher cognitive vulnerability and higher baseline physical activity levels would be associated with greater mood disturbance during the exercise cessation phase, relative to lower scores on either of these constructs. To test this hypothesis, a similar LMM analysis to that for hypothesis 4 was used to examine the interaction of each cognitive vulnerability variable by baseline physical activity level in prediction of the mood measures (i.e., BDI-II, BAI, POMS Brief scores). In each model, the mood measure (i.e., BDI, BAI, POMS Brief) was modeled as a function of the cognitive vulnerability variable, baseline physical activity level, and their interactions with covariates from the primary analyses (i.e., hypotheses 1 and 2) and covariates from the previous hypothesis included in the model. Nested model comparisons using likelihood ratio tests were used to determine the best fitting model, and significant interactions were explored graphically post-hoc. It was predicted that the cognitive vulnerability variable by baseline physical activity interactions would be significant predictors of change in mood disturbance, above and beyond the main effects observed from these variables, such that higher levels on both constructs would be associated with greater increases in depressive and anxiety symptoms over the course of the study.

3.5. Sample Size Considerations

Statistical power for the proposed analyses were computed using the G*Power, Version 3.1.2 software for the primary aims (Faul, Erdfelder, Buchner, & Lang, 2009). Because no previous studies have examined the relation between cognitive vulnerability and mood symptomatology in an exercise withdrawal paradigm, previous literature did not provide estimates of effect sizes. Therefore, a conservative but meaningful estimate of effect size was utilized in the power analysis. It was determined that with an alpha of .05, correlation between repeated measures of .50 with 4 time points, and power of .90, a total sample size of 30 would be needed to detect a medium effect size (f=.25).

CHAPTER 4: RESULTS

4.1. Participant Flow and Missing Data

The sample included 36 eligible community adults who completed study visit 1, 32/36 (89%) of whom completed the entirety of the study, including the mail-in questionnaires and study visits 2 and 3. Of the 4 individuals who did not complete the study, 1 lost the activity monitor after the initial study visit and did not complete the remainder of the protocol, 1 withdrew due to changes in work schedule, 1 withdrew due to injury unrelated to study protocol, and 1 failed to complete the mail-in questionnaires or return for study visit 3. The latter participant completed study visit 2 but not the mail-in questionnaires or study visit 3, bringing the completion total at study visit 2 to 33/36 (92%). Missing data was minimal: All participants who attended study visits 2 and 3 and completed the mail-in questionnaires provided data on the outcome mood measures at those time points. Of the 33 participants who completed study visit 2, data was provided on all self-report measures with the exception of the Dysfunctional Attitudes Scale, Coping Inventory for Stressful Situations, and cognitive reactivity, which was available for 32/33, 32/33, and 31/33 participants, respectively, due to experimenter error. The missingness of depression and anxiety scores on the BDI-II, BAI, and POMS Brief appears unrelated to the predicted values on these outcome measures; therefore, it can be assumed that the data is missing at random. Maximum likelihood estimation methods were utilized in the analyses to address this missing data.

Activity monitor data was available for 32/36 (89%) participants during the maintained exercise phase (between study visits 1 and 2) and for 26/36 (72%) participants during the exercise cessation phase (between study visits 2 and 3) of the study. Missing data for a phase of the study was either due to study equipment malfunction (n = 1 during maintained exercise phase; n = 6 during exercise cessation phase) or a participant dropping out of the study (n = 3 during maintained exercise phase; n = 4 during exercise cessation phase). Participants wore the activity monitors, on average, during 86.0% (*SD* = 16.4) of the time during the maintained exercise phase and 79.8% (*SD* = 20.4) of the time during the exercise cessation phase. Of the subsample with valid activity monitor data, 22/32 (69%) and 13/26 (50%) wore the activity monitor for $\geq$ 85% of the time during the maintained exercise phase and the exercise cessation phase, respectively. Therefore, the majority of participants had ActiGraph accelerometer data for a substantial proportion of the 4-week study protocol. The percentage of wear time observed in the current study is equivalent to or greater than adherence rates observed in studies examining accelerometer protocols in various populations (Sharpe et al., 2011; Troiano et al., 2008). Mean vector magnitude activity counts were 34227273.4 (*SD* = 10448686.8) for the maintained exercise phase and 28949307.3 (*SD* = 8205510.7) for the exercise cessation phase. The decrease in activity between the study phases was statistically significant ($t(25) = 3.07$, $p = .005$), implying adherence to the exercise cessation protocol for the sample, overall. Of note, of the subsample with valid activity count measurements during both phases, 7 participants (19.4%) showed an increase in activity during the exercise cessation phase relative to the maintained exercise phase. This finding, however, does not necessarily imply deviation from the exercise cessation protocol for the 7 participants, given both the confounding factor of time that the activity monitor was actively worn over each 2-week phase (i.e., the activity monitor was worn for a greater amount of time during the exercise cessation phase compared to the maintained exercise phase for 3 of these 7 participants), and participants' engagement in physical activity unrelated to defined exercise (i.e., any aerobic and non-aerobic physical activity that participant engages in with the purpose of getting a workout), which was permitted during the exercise cessation phase of the study (e.g., work around the house, physical activity for transportation).

4.2. Sample Baseline Characteristics and Descriptive Statistics

Table 3 presents demographic information for the entire sample (*N*=36). This sample of community adults was primarily female (77.8%), Caucasian (86.1%), and single (61.1%) with a mean age of 30.5 years. Roughly 8% of the sample met DSM-IV-TR criteria for a current Axis I diagnosis and 17% met criteria for a previous major depressive episode based on the SCID administered at baseline.

Table 3: Characteristics of Sample (*N*=36)

Age (years), *M* (*SD*)	30.5 (13.5)
Sex	
Male	8 (22.2%)
Female	28 (77.8%)
Race	
White	31 (86.1%)
Asian	4 (11.1%)
African American	1 (2.8%)
Marital status	
Married	9 (25.0%)
Engaged	2 (5.6%)
Cohabiting with partner	3 (8.3%)
Single	22 (61.1%)
Highest education level	
Some high school	1 (2.8%)

High school degree	11 (30.6%)
Some college	2 (5.6%)
College degree	14 (38.9%)
Graduate degree	8 (22.2%)
Current Axis I diagnosis	
Yes	3 (8.3%)
No	33 (91.7%)
Past depressive episode	
Yes	6 (16.7%)
No	30 (83.3%)

Note. Data are presented as No. (%) unless otherwise indicated.

Table 4 presents descriptive statistics for the mood outcome measures administered at study visits 1, 2 and 3, and as part of the mail-in questionnaires completed 1 week into the exercise cessation phase. Although the current study only utilized the Tension and Depression subscales of the POMS Brief in the statistical analyses, the additional subscales are included in the table. BDI-II scores increased over the course of the study from M = 1.7 (SD = 3.2) at study visit 1 to M = 6.0 (SD = 4.4) and M = 6.6 (SD = 5.2) at the mail-in assessment and study visit 3, respectively. Similarly, scores on the Tension subscale of the POMS Brief increased from M = 1.4 (SD = 1.4) at study visit 1 to M = 2.2 (SD = 2.1) and M = 2.7 (SD = 2.2) at the mail-in assessment and study visit 3, respectively. Scores on the Depression subscale of the POMS Brief followed a similar trend, increasing from M = 0.8 (SD = 1.0) initially to M = 1.6 (SD = 2.1) and M = 2.0 (SD = 2.5) at the mail-in assessment and study visit 3, respectively. In contrast to these outcome measures, BAI scores remained relatively stable over the course of the study with mean scores (*SD*) of 3.5 (5.1), 2.8 (3.3) and 3.6 (4.9) at study visit 1, mail-in assessment, and study visit 3, respectively.

Table 4: Descriptive Statistics for Mood Outcome Measures

	Mean	SD	Min.	Max.
Time 1: Visit 1 (Baseline; N=36)				
BDI-II	1.7	3.2	0	17
BAI	3.5	5.1	0	54
POMS Brief: Total mood disturbance	-4.2	4.4	-15	7
Tension subscale	1.4	1.4	0	4
Depression subscale	0.8	1.0	0	4
Anger subscale	0.8	1.1	0	4
Vigor subscale	11.1	2.9	6	18
Fatigue subscale	1.2	1.2	0	5
Confusion subscale	2.7	1.1	1	5
Time 2: Visit 2 (Maintained exercise phase; n=33)				
BDI-II	1.7	3.0	0	12
BAI	2.7	3.5	0	12
POMS Brief: Total mood disturbance	-5.3	5.5	-16	12
Tension subscale	1.5	1.8	0	7
Depression subscale	0.6	1.0	0	4
Anger subscale	0.4	1.0	0	4
Vigor subscale	12.0	3.8	4	20
Fatigue subscale	1.4	1.5	0	6
Confusion subscale	2.8	1.3	0	5
Time 3: Mail-in questionnaires (Exercise cessation phase week 1; n=32)				
BDI-II	6.0	4.4	0	15
BAI	2.8	3.3	0	13
POMS Brief: Total mood disturbance	3.53	9.2	-10	23
Tension subscale	2.2	2.1	0	8
Depression subscale	1.6	2.1	0	7
Anger subscale	1.5	1.8	0	6
Vigor subscale	6.9	4.0	0	14
Fatigue subscale	2.3	2.3	0	8
Confusion subscale	2.9	1.6	0	6
Time 4: Visit 3 (Exercise cessation phase week 2; n=32)				
BDI-II	6.6	5.2	1	24
BAI	3.6	4.9	0	24
POMS Brief: Total mood disturbance	5.3	10.5	-12	40
Tension subscale	2.7	2.2	0	8
Depression subscale	2.0	2.5	0	11
Anger subscale	1.8	2.0	0	8
Vigor subscale	6.6	4.8	0	16
Fatigue subscale	2.6	2.4	0	10
Confusion subscale	2.9	1.7	0	7

Note. BDI-II = Beck Depression Inventory, 2nd Edition; BAI = Beck Anxiety Inventory; POMS Brief = Profile of Mood States, Brief Version.

Tables 5 and 6 depict bivariate correlations between the anxiety (i.e., BAI and POMS Brief–Tension subscale) and depression measures (i.e., BDI-II and POMS Brief–Depression subscale), respectively. In general, these measures were significantly correlated with one another, with the exception of the BAI and POMS Brief–Tension subscale at study visit 1. These results suggest stronger correlations during the exercise cessation phase for both constructs, relative to the maintained exercise phase. Based on results from the SCID interview conducted at study visit 3, 1 of the 32 participants (2.8%) who provided data met DSM-IV-TR criteria for a current major depressive episode at the conclusion of the exercise cessation phase.

Table 5: Correlations Between Anxiety Construct Outcome Measures

	BAI (Visit 1)	BAI (Visit 2)	BAI (Mail-in)	BAI (Visit 3)
POMS Brief: Tension (Visit 1)	.32			
POMS Brief: Tension (Visit 2)		.66**		
POMS Brief: Tension (Mail-in)			.76**	
POMS Brief: Tension (Visit 3)				.75**

Note. BAI = Beck Anxiety Inventory; POMS Brief: Tension = Profile of Mood States, Brief Version - Tension subscale.

* $p < .05$ ** $p < .01$

Table 6: Correlations Between Depression Construct Outcome Measures

	BDI-II (Visit 1)	BDI-II (Visit 2)	BDI-II (Mail-in)	BDI-II (Visit 3)
POMS Brief: Depression (Visit 1)	.41*			
POMS Brief: Depression (Visit 2)		.49**		
POMS Brief: Depression (Mail-in)			.83**	
POMS Brief: Depression (Visit 3)				.85**

Note. BDI-II = Beck Depression Inventory, Second Edition; POMS Brief: Depression = Profile of Mood States, Brief Version - Depression subscale.

* $p < .05$ ** $p < .01$

Descriptive information about the predictor variables, including the cognitive vulnerability variables and self-report measures, is presented in Table 7. The results indicate a fairly large range of responses on all measures, indicating variability in the study sample. When determining cognitive reactivity, a variable which is calculated from the post-mood induction Dysfunctional Attitudes Scale (DAS) score minus the pre-mood induction DAS score, the visual analog scale (VAS) values for participants were also examined. VAS scores decreased significantly over the negative mood induction ($t(31) = 7.36$, $p < .001$) with the mean (*SD*) values of 39.6 (16.9) pre- and -5.8 (30.1) post-mood induction. This pattern suggests a "successful" dysphoric mood induction, as negative values correspond to feelings of sadness and positive values represent reported happiness. Of note, 4/32 (12.5%) participants did not experience the expected deterioration in mood based on the VAS, and instead reported no change or an improvement in mood from pre- to post-mood induction. This percentage is within previously reported ranges of participants who do not experience the expected decrease in mood over a negative mood induction (Jarrett et al., 2012).

Table 7: Descriptive Statistics of Predictors

	Possible Range	Mean	SD	Min.	Max.
RRS: Brooding subscale (*n*=33)	0 - 33	5.82	4.69	0	19
DAS (Form A) (*n*=32)	40 - 280	101.78	21.28	69	159
Cognitive Reactivity (*n*=31)	-240 - 240	14.10	15.27	-38	34
FSS (*n*=33)	10 - 50	20.73	7.28	10	48
REI: Stress / Mood Management subscale (*n*=33)	1 - 7	4.64	1.17	2	6.75
CISS: Exercise subscale (*n*=32)	3 - 15	11.16	2.93	4	15
DERS (*n*=33)	36 - 180	55.18	9.99	38	88
EBQ: Mental / Emotional Functioning subscale (*n*=33)	0 - 100	33.69	21.94	0	78.57
ACLS PAQ: MET-hrs/week of exercise (*N*=36)	NA	43.68	19.78	18.2	94

Note. RRS = Ruminative Responses Scale; Cognitive Reactivity = DAS post-mood induction – DAS pre-mood induction; DAS = Dysfunctional Attitudes Scale; FSS = Fatigue Severity Scale; REI = Reasons for Exercising Inventory; CISS = Coping Inventory for Stressful Situations; DERS = Difficulties in Emotion Regulation Scale; EBQ = Exercise Beliefs Questionnaire; ACLS PAQ = Aerobics Center Longitudinal Study Physical Activity Questionnaire.

4.3. Primary Analyses Hypotheses 1 and 2

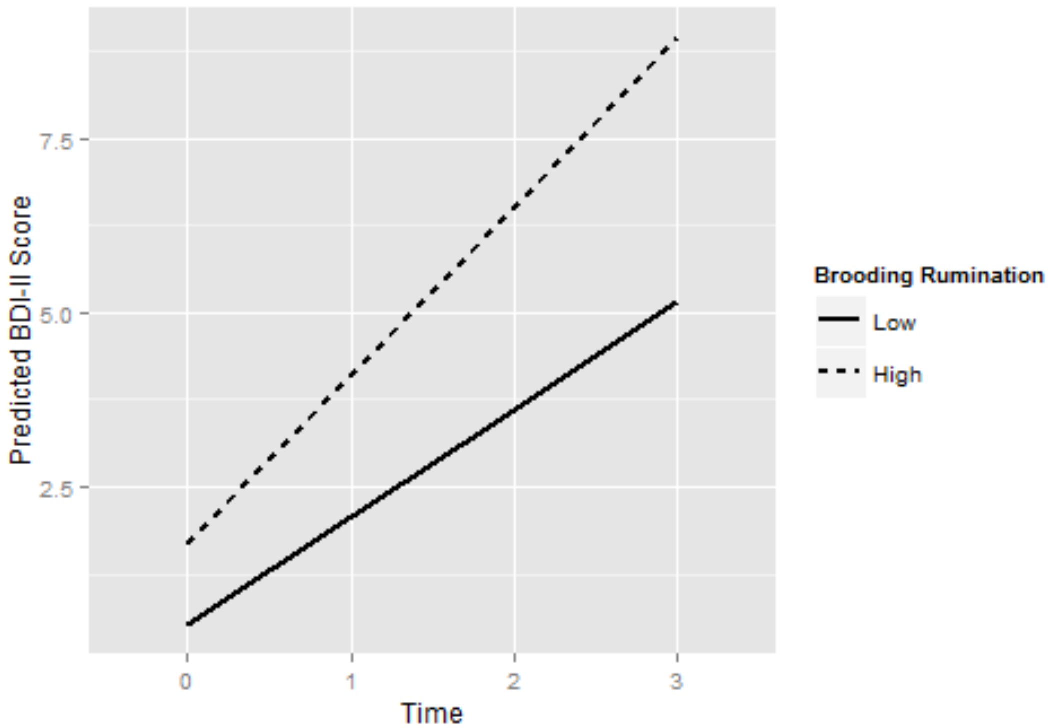
For the BDI-II, BAI, and POMS Brief-Depression subscale, comparisons of covariance structures indicated that the unstructured covariance matrix was the best fit for the data. Results presented here, therefore, interpret the unstructured covariance matrix fixed effects from those models, while utilizing the standard (lme4) method for estimating the fixed effects. For the POMS Brief-Tension subscale, the standard model emerged as the best fit for the data when comparing covariance structures; therefore, those fixed effects are presented here.

Comparisons of unconditional models found the best fitting models for the BDI-II and POMS-Brief Depression and Tension subscales included a linear time predictor as a fixed and random effect. In prediction of BAI scores, although comparisons suggested the use of a quadratic term, the final unconditional model did not include a time predictor, indicating that anxiety scores did not significantly change over the course of the study. This decision was based upon theoretical considerations, given that a steady increase in mood symptoms was expected over the exercise cessation phase, based on previous literature, and no significant change in symptoms over the maintained exercise phase. The results from the unconditional models are supported by the observed boxplots of ordinary least squares residuals. More specifically, there did not appear to be a clear time trend observed in means of the residuals, and therefore a quadratic term did not appear to be indicated in any of the models.

The equation for the best fitting model in the prediction of BDI-II scores suggests that individuals with average levels of brooding rumination, dysfunctional attitudes, and cognitive reactivity had an initial depression severity score of 2.08. There was a significant main effect of time, such that depression severity increased by 1.21 at each subsequent time point (i.e., from baseline to post-two weeks of maintained exercise to post-one and two weeks of exercise cessation). Furthermore, there was a significant main effect of brooding rumination, such that for each 1-unit increase in brooding rumination, there is a .26 increase in depression score at baseline, which is maintained over time. A main effect for dysfunctional attitudes or cognitive reactivity was not found in this model. Additionally, the best fitting model did not include the time by cognitive vulnerability interactions.

Exploratory analyses with a secondary model found a marginally significant brooding rumination by time interaction, which may qualify the main effects of both. Explored graphically (Figure 1), levels of brooding rumination may interact differently with time in the prediction of depressive symptoms as measured by the BDI-II. Depression scores across subjects increased over time; however, individuals with higher levels of brooding rumination had a greater increase in depressive symptoms (slope) over time. From this, it can be concluded that individuals with high levels of brooding rumination may be at increased risk for depressive symptoms as measured by the BDI-II over a period of exercise cessation.

Figure 1: Brooding Rumination by Time Interaction in Prediction of BDI-II Scores

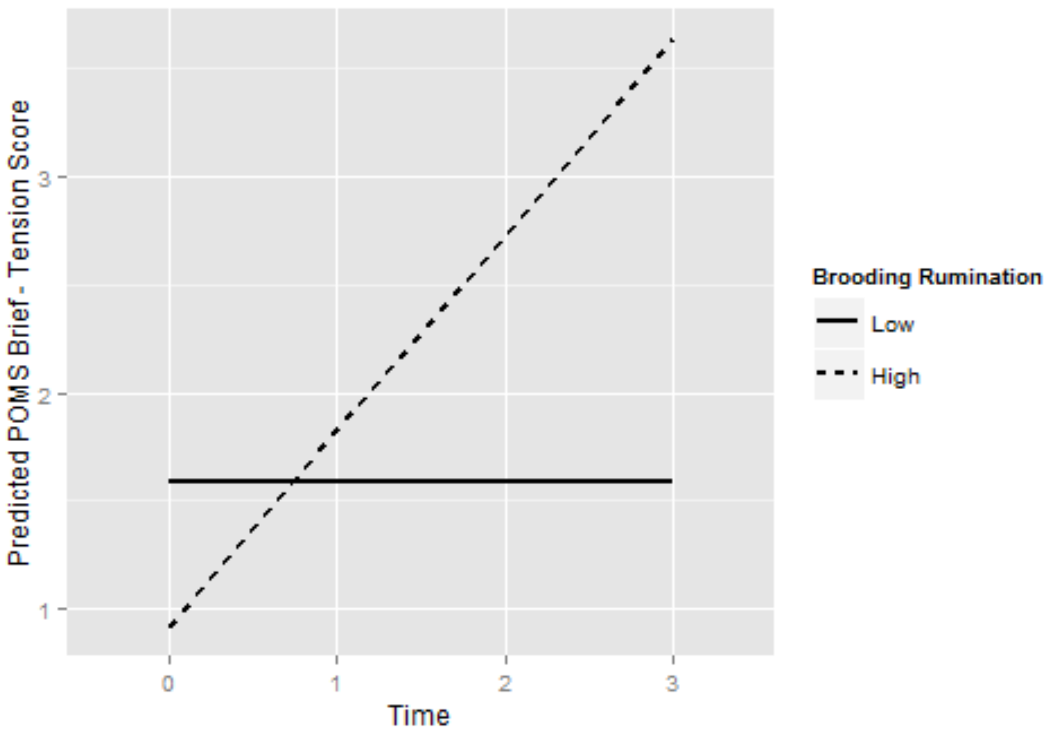


Note. Brooding rumination is measured via the Ruminative Responses Scale with lines representing high and low levels of this construct (±1 standard deviation above and below the mean); BDI-II = Beck Depression Inventory, 2^{nd} Edition.

In the prediction of BAI scores, the best fitting model suggests that individuals with average levels of brooding rumination, dysfunctional attitudes, and cognitive reactivity had an initial anxiety severity score of 2.55. This model did not include a time predictor, suggesting that anxiety scores as measured by the BAI did not change over the course of the study. The adopted model suggests a marginally significant effect of brooding rumination, such that for each 1-unit increase in brooding rumination, there was a .12 increase in anxiety scores. Collapsing across time, it appears that higher levels of brooding rumination may be predictive of higher levels of anxiety as measured on the BAI. As the best fitting model did not include a time predictor, time by cognitive vulnerability interactions were not included in the model.

In prediction of POMS Brief–Tension subscale scores, the best fitting model suggests that individuals with average levels of brooding rumination, dysfunctional attitudes, and cognitive reactivity had an initial score of 1.25. The adopted model suggests a significant main effect of time, such that anxiety scores increased by 0.45 at each subsequent time point. This model also suggests a significant time by brooding rumination interaction that qualifies this main effect of time. Explored graphically (Figure 2), it appears that levels of brooding rumination interacted differently with time in the prediction of anxiety symptoms as measured by the POMS Brief. More specifically, an increase in anxiety symptoms over time was only evident among individuals with higher levels of brooding rumination, therefore implying that individuals with higher levels of brooding rumination were at increased risk for anxiety symptoms as measured by the POMS Brief over the period of exercise cessation. A main effect of dysfunctional attitudes and cognitive reactivity was not found in this model. Additionally, the final adopted model did not include time by dysfunctional attitudes or time by cognitive reactivity interactions.

Figure 2. Brooding Rumination by Time Interaction in Prediction of POMS Brief-Tension Subscale Scores

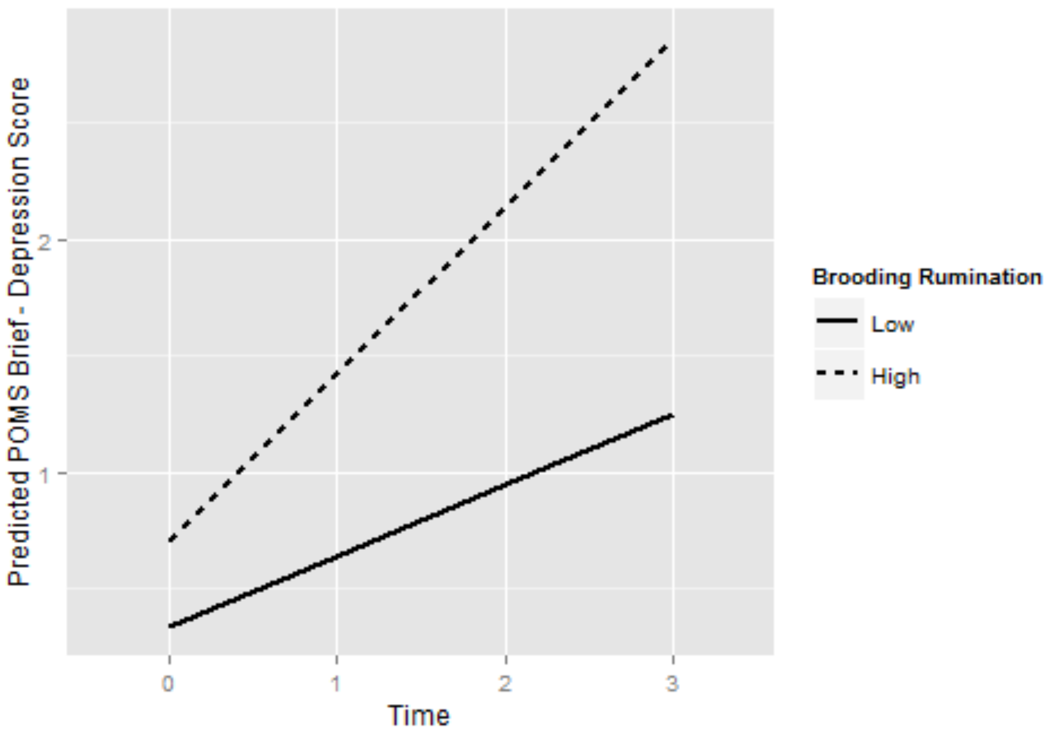


Note. Brooding rumination is measured via the Ruminative Responses Scale with lines representing high and low levels of this construct (±1 standard deviation above and below the mean); POMS Brief = Profile of Mood States - Brief Version.

In prediction of POMS Brief–Depression scores, results suggest that individuals with average levels of brooding rumination, dysfunctional attitudes, and cognitive reactivity had a POMS Brief-Depression subscale score of .39 at baseline. The data indicates a significant main effect of time, such that depression scores measured by the POMS Brief increased by .28 at each subsequent time point. This model, which did not include time by cognitive vulnerability interactions, did not find a significant main effect of brooding rumination, dysfunctional attitudes, or cognitive reactivity.

Exploratory analyses with a secondary model, however, found a marginally significant time by brooding rumination interaction, which may qualify the main effect of time. Figure 3 presents graphical exploration of this interaction, which suggests that levels of brooding rumination may interact differently with time in the prediction of depressive symptoms as measured by the POMS Brief. Depression scores across subjects increased over time; however, individuals with higher levels of brooding rumination experienced a greater increase in depressive scores relative to individuals with lower levels of brooding rumination. Therefore, it can be concluded that individuals with higher levels of brooding rumination may be at increased risk for depressive symptoms on the POMS Brief over a period of exercise cessation.

Figure 3: Brooding Rumination by Time Interaction in Prediction of POMS Brief-Depression Subscale Scores



Note. Brooding rumination is measured via the Ruminative Responses Scale with lines representing high and low levels of this construct (±1 standard deviation above and below the mean); POMS Brief = Profile of Mood States - Brief Version.

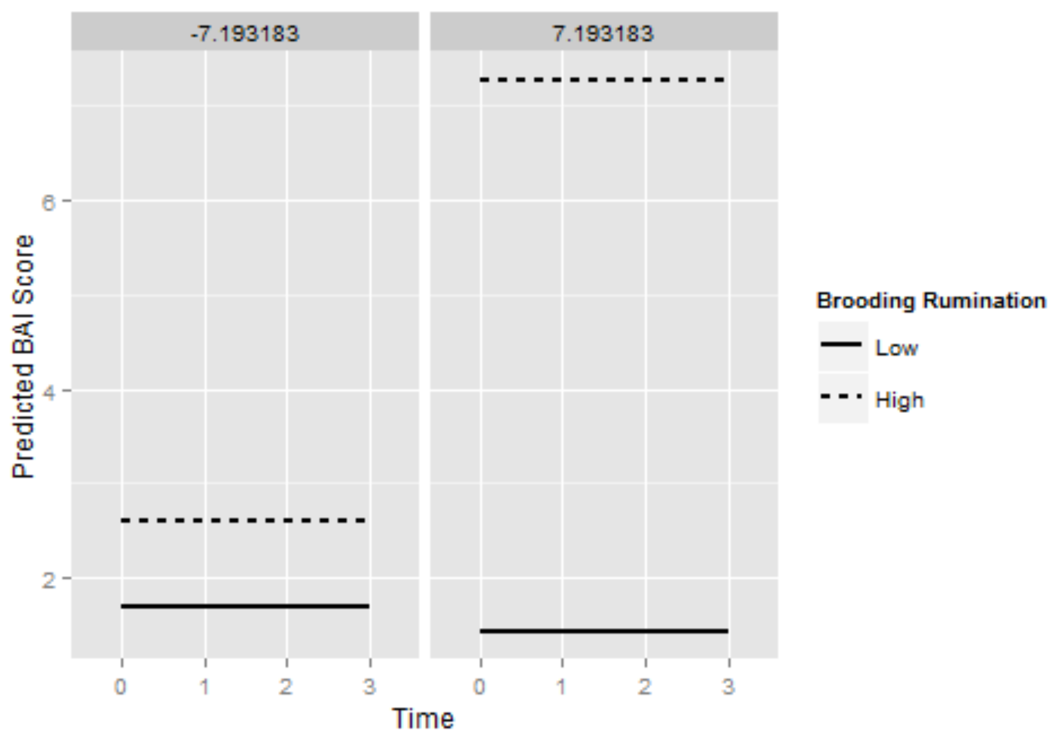
Additional analyses were run to include the covariates of age, sex, and past major depressive episode in the best fitting models presented above. The significant results were maintained with these covariates added to the models. Furthermore, analyses were run including only participants who had a "successful" mood induction (i.e., not including the 4 participants who reported no change or an improvement in mood pre- to post-mood induction on the VAS), as defined above. Cognitive reactivity remained non-significant, indicating that this null finding holds within this conservative subsample of participants.

4.4. Secondary Analyses I: Hypotheses 3 and 4

In prediction of BDI-II scores, the final adopted model included the fixed effects of fatigue severity and emotion dysregulation, in addition to a linear predictor of time and the cognitive vulnerability variables. This model suggests main effects of both time and brooding rumination, as described in the primary analyses. Additionally, there was a significant main effect of fatigue severity and a marginally significant effect of emotion dysregulation. More specifically, for each 1-unit increase in fatigue severity on the FSS, there was a .24 increase in depression severity at baseline, which was maintained over time. The model also suggested a marginally significant effect of emotional dysregulation, such that for each 1-unit increase on the DERS, there was a .07 increase in depression severity at baseline, which was maintained over time. Similar results were found when also including the time by brooding rumination interaction in the model. This final adopted model did not include the cognitive vulnerability by fatigue severity, cognitive vulnerability by emotion dysregulation, time by fatigue severity, or time by emotion dysregulation interactions.

In prediction of BAI scores, the final adopted model included the fixed effect of fatigue severity and the brooding rumination by fatigue severity interaction, as well as the fixed effects of the cognitive vulnerability variables, as described in the primary analyses. Collapsed across time points, there were significant effects of both fatigue severity and brooding rumination. These main effects are qualified by a significant brooding rumination by fatigue severity interaction. Explored graphically (Figure 4), the data indicates that collapsed across time points, brooding rumination interacted with fatigue severity to differentially predict anxiety scores, as measured by the BAI. More specifically, the combination of high levels of both brooding rumination and high levels of fatigue severity was associated with increased anxiety scores compared to individuals who scored low on either of these measures.

Figure 4: Brooding Rumination by Fatigue Severity Interaction in Prediction of BAI Scores



Note. Side-by-side panels represent high and low levels (±1 standard deviation above and below the mean) of fatigue severity measured via the Fatigue Severity Scale; Brooding rumination is measured via the Ruminative Responses Scale with lines representing high and low levels of this construct (±1 standard deviation above and below the mean); BAI = Beck Anxiety Inventory.

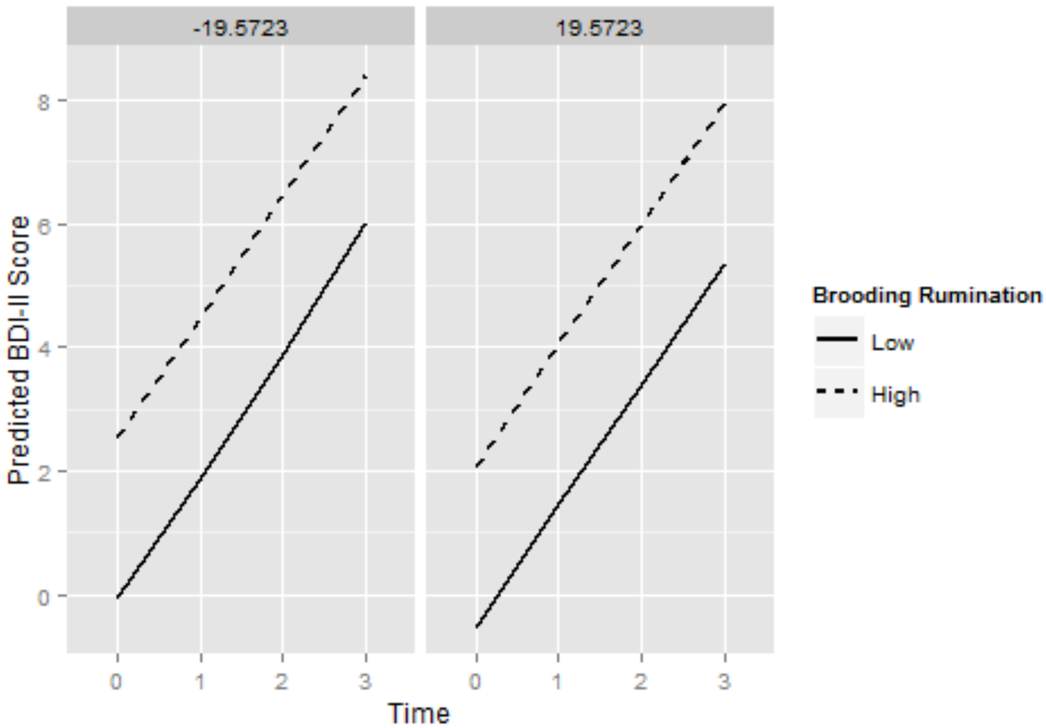
The final adopted model in prediction of POMS Brief–Tension subscale scores included the fixed effects of fatigue severity and reasons for exercising (REI)–mood/stress management subscale, in addition to the fixed effects of a linear predictor of time, the cognitive vulnerability variables, and the time by brooding rumination interaction, as described in the primary analyses. This model suggests significant main effects of time and brooding rumination, and a significant time by brooding rumination interaction, as previously described. Additionally, the model suggests a significant main effect of REI–stress/mood management and a marginally significant effect of fatigue severity on anxiety scores as measured by the POMS Brief. More specifically, for each 1-unit increase on the REI–stress/mood management subscale, there was a .60 increase in anxiety severity at baseline, which was maintained over time. The marginally significant effect of fatigue severity suggests that for each 1-unit increase on this measure, there was a .05 increase in anxiety severity at baseline, again maintained over time. The final adopted model did not include the cognitive vulnerability by reasons for exercising, cognitive vulnerability by fatigue severity, time by reasons for exercising, or time by fatigue severity interactions.

The final adopted model in prediction of POMS Brief–Depression subscale scores included the fixed effect of coping inventory for stressful situations (CISS)–exercise subscale, in addition to the fixed effects of a linear predictor of time, the cognitive vulnerability variables, and the time by brooding rumination interaction, as described in the primary analyses. This model suggests similar findings, such that there is a significant main effect of time and a marginally significant time by brooding rumination interaction. Additionally, there is a significant main effect of the CISS–exercise subscale on depression scores as measured by the POMS Brief. For each 1-unit increase on the exercise subscale of the CISS, there was a .12 increase in depression severity at baseline, which was maintained over time. The final adopted model did not include the cognitive vulnerability by CISS–exercise subscale or time by CISS-exercise subscale interactions.

4.5. Secondary Analyses II: Hypotheses 5 and 6

In prediction of BDI-II scores, the final adopted model included the fixed effects of baseline physical activity level (estimated as energy expenditure in MET-hours per week) and a baseline physical activity level by brooding rumination interaction, in addition to a linear predictor of time and the cognitive vulnerability variables. This model suggests a main effect of time and brooding rumination, as described in the primary analyses. Additionally, there was a significant baseline physical activity by brooding rumination interaction, explored graphically (Figure 5), which qualifies the main effect of brooding rumination. The graph suggests that individuals with higher levels of brooding rumination had greater depressive symptoms relative to individuals with lower levels of brooding, as was the case described in the primary analyses. Furthermore, the graph suggests that the combination of low levels of baseline physical activity and high levels of brooding rumination put individuals at an even higher risk for the development of depressive symptoms, as measured by the BDI-II. Additionally, the combination of low levels of brooding rumination and high levels of baseline physical activity appeared to be protective in the development of BDI-II depressive symptoms over a period of exercise cessation.

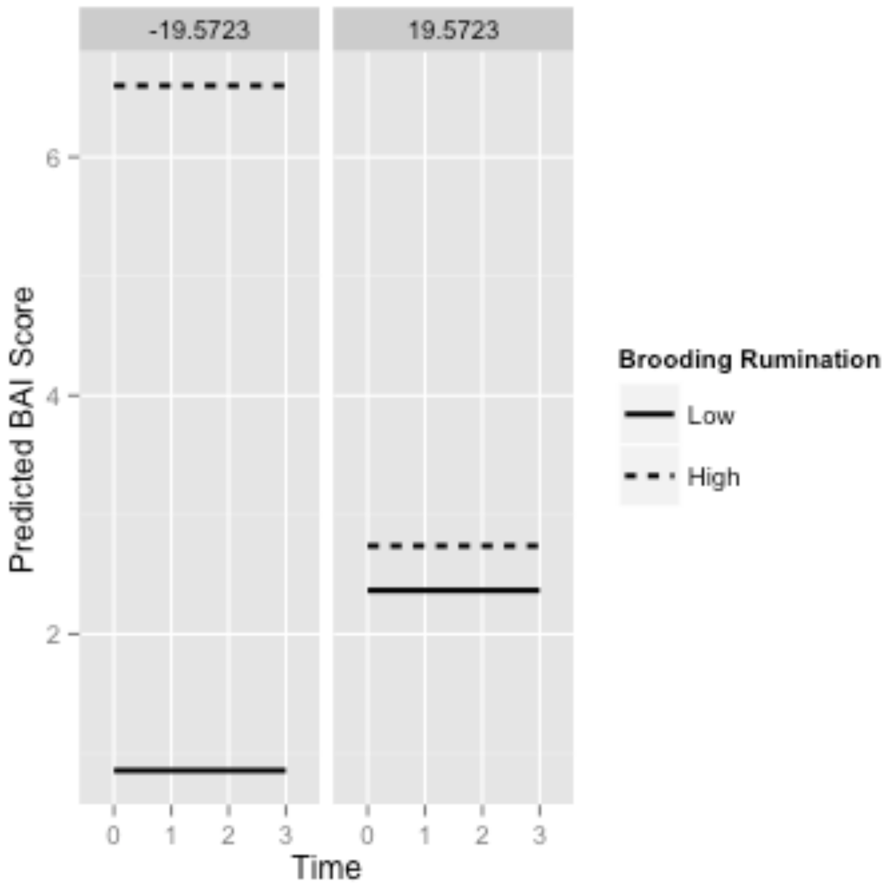
Figure 5: Brooding Rumination by Baseline Physical Activity Interaction in Prediction of BDI-II Scores



Note. Side-by-side panels represent high and low levels (±1 standard deviation above and below the mean) of baseline physical activity (estimated as energy expenditure in MET - hours per week as derived from the Aerobics Center Longitudinal Study Physical Activity Questionnaire); Brooding rumination is measured via the Ruminative Responses Scale with lines representing high and low levels of this construct (±1 standard deviation above and below the mean); BDI-II = Beck Depression Inventory, 2nd Edition.

In prediction of BAI scores, the final adopted model included the fixed effects of baseline physical activity and the physical activity by brooding rumination interaction, in addition to the cognitive vulnerability variables. Results indicate a significant main effect of brooding rumination, which is qualified by a significant physical activity by brooding rumination interaction, explored graphically in Figure 6. The graph suggests that the combination of high levels of brooding rumination and low levels of baseline physical activity was associated with higher anxiety scores on the BAI. This result implies that collapsed across all time points, the main effect of brooding rumination is mainly important in the context of lower levels of baseline physical activity, thereby predicting higher anxiety responses in this subset of participants.

Figure 6: Brooding Rumination by Baseline Physical Activity Interaction in Prediction of BAI Scores



Note. Side-by-side panels represent high and low levels (±1 standard deviation above and below the mean) of baseline physical activity (estimated as energy expenditure in MET - hours per week as derived from the Aerobics Center Longitudinal Study Physical Activity Questionnaire); Brooding rumination is measured via the Ruminative Responses Scale with lines representing high and low levels of this construct (±1 standard deviation above and below the mean); BAI = Beck Anxiety Inventory.

In prediction of both the POMS Brief-Tension and Depression subscale scores, results indicate that the fixed effects of baseline physical activity and the physical activity by cognitive vulnerability interactions did not significantly improve model prediction. The best fitting models were the parsimonious models, determined from the primary analyses, which did not include these additional covariates.

CHAPTER 5: DISCUSSION

This study used an exercise cessation protocol in a sample of healthy, regular exercisers to examine the predictive effects of cognitive vulnerability constructs, psychological self-report measures, and baseline physical activity level on the development of depressive and anxiety symptoms. Results are interpreted and discussed below, corresponding with study aims and hypotheses.

5.1. Aim 1

The first aim was to replicate and extend prior findings on the development of mood disturbance over a period of exercise cessation. As predicted, a significant main effect of time was found in prediction of depressive symptoms as measured by the BDI-II and the POMS Brief-Depression subscale, and in prediction of anxiety symptoms as measured by the POMS Brief-Tension subscale, indicating that symptoms increased over time (i.e., from baseline to post-two weeks of maintained exercise to post-one and two weeks of exercise cessation). These results support the conclusion that periods of exercise cessation are associated with increased mood symptoms and are congruent with prior correlational (e.g., Conboy, 1994; Johnston & Carroll, 2000; Robbins & Joseph, 1985) and experimental longitudinal designs (e.g., Berlin et al., 2006; Glass et al., 2004; Mondin et al., 1996) with varied mood outcome measures.

In comparison to prior experimental designs that utilized the same outcomes[1] as the current study, results presented here are similar. Mondin and colleagues (1996) used the depression and tension subscales of the POMS, as well as the State-Trait Anxiety Inventory and the Depression Adjective Checklist, to compare participants' self-reported

[1] The POMS and BDI, which are used in previous studies, are considered here to be very similar to the POMS Brief and BDI-II used in the current study.

mood on 3 days of experimentally manipulated non-exercise vs. 2 days of regular exercise. These authors found a significant increase in anxiety and depression on non-exercise days, with mean scores on the tension subscale of the POMS subscales ranging from 10.5–16.2 (vs. 7.5–7.7 on exercise days) and mean scores on the depression subscale ranging from 4.4–9.3 (vs. 2.6–3.6) on non-exercise days. Similarly, Berlin et al.'s (2006) study found an increase in anxiety symptoms as measured by the tension subscale of the POMS over a 2-week period of exercise cessation: M=7.63 (5.5) in the exercise cessation group vs. M=4.5 (4.5) in the maintained exercise control group. Although the POMS Brief has been shown to correlate strongly with the 60-item POMS, direct comparisons cannot be made between scores in previous studies using the POMS and scores reported in the current study utilizing the POMS Brief (McNair, Lorr, & Droppleman, 1992). Nonetheless, results from the current study are congruent with previously reported experimental designs that utilized the POMS to assess depressive and anxiety symptoms.

Our results were also similar to prior studies utilizing the BDI or BDI-II to measure depressive symptoms. In an experimental design with a 1-week exercise cessation phase, Glass and colleagues (2004) used the BDI to measure depressive symptoms. These authors found that approximately 50% of the sample (8/18 participants) experienced a significant worsening of self-reported pain, fatigue, or mood symptoms (defined as a 10% or greater increase in symptoms relative to baseline measures) following the 1-week period of exercise cessation. Of these individuals, three experienced such a worsening in mood symptoms, as measured by the BDI or the State-Trait Anxiety Inventory. In this subsample of participants (n=3), BDI scores increased an average of 3 points from pre- to post- exercise cessation. Similarly, in Berlin et al.'s (2006) experimental design in which participants were randomized to two weeks of exercise cessation or two weeks of maintained exercise, the exercise cessation group had significantly higher BDI-II scores relative to the maintained exercise group at the end of the study protocol (*M*=4.72 (3.3) vs. *M*=1.44 (2.6)). The general trend of greater depressive symptoms and the relative increase in BDI-II scores observed in the current study replicate previous findings. More specifically, the mean BDI-II increase of 4.3 points after one week and 4.9 points after two weeks of exercise cessation observed here is similar to the degree of increase in depressive symptoms in the above mentioned studies (Berlin et al., 2006; Glass et al., 2004).

Interestingly, a main effect of time was not found in prediction of scores on the BAI, indicating that anxiety symptoms on the BAI did not significantly change over the exercise cessation protocol. This result is surprising and incongruent with the previously reported main effects of time for the other mood outcome measures, including the POMS Brief-Tension subscale. However, the differences in results between the BAI and POMS Brief-Tension subscale may be explained by dissimilarities between these two measures. The BAI consists of 21 items assessing physiological, as well as cognitive and affective components of anxiety, whereas the items on the POMS Brief assess general affective states (e.g., "tense," "uneasy," "nervous" on the Tension subscale). Therefore, these results may indicate that a period of exercise cessation is associated with an increase in the affective component of anxiety, but not the physiological or cognitive changes associated with this construct. To our knowledge, this is the first study to date that has utilized the BAI as an outcome measure in an exercise cessation paradigm; therefore, further studies are needed to replicate this finding.

5.2. Aim 2

The second aim was to examine well-established cognitive vulnerability constructs in the unipolar depression field as predictors of mood disturbance during a period of exercise cessation. To do so, the main effects of dysfunctional attitudes, cognitive reactivity, and brooding rumination, as well as the time by cognitive vulnerability interactions were examined in prediction of depressive and anxiety symptoms over an exercise cessation protocol. Results from these analyses were mixed, with support for brooding rumination, but not dysfunctional attitudes or cognitive reactivity, as a risk factor for mood disturbance during a period of exercise cessation.

There was a significant main effect of brooding rumination in prediction of BDI-II scores, and a marginally significant main effect of brooding rumination in prediction of BAI scores. Furthermore, there was a significant time by brooding rumination interaction in prediction of POMS Brief-Tension scores, and a marginally significant time by brooding rumination interaction in prediction of POMS Brief-Depression and BDI-II scores, thus qualifying the main effects in these models. The clearest pattern of results was evident on the POMS Brief-Tension subscale, whereby brooding rumination served to differentiate individuals who experienced an increase in anxiety over a period of exercise cessation (i.e., the increase in scores was only present in individuals with higher levels of baseline brooding rumination). Although only marginally significant, a similar pattern was found when examining BDI-II and POMS Brief-Depression scores, such that brooding rumination served as a risk factor for the development of mood symptoms during a period of exercise cessation. In both of these models, depression and anxiety symptoms increased over time, however, individuals with higher levels of brooding rumination experienced a greater increase in such symptoms relative to individuals who scored lower on this construct.

Taken as a whole, these results are in line with prior research on rumination in the unipolar depression field, suggesting that rumination is a predictor of depressive symptoms (including severity and duration) and the development of depressive episodes over time (Just & Alloy, 1997; Nolan et al., 1998; Nolen-Hoeksema et al., 1994; 1999; Nolen-Hoeksema & Davis, 1999; Nolen-Hoeksema & Morrow, 1991; Sarin et al., 2005; Wood et al., 1990). These results, therefore, extend this literature to the exercise cessation field and highlight brooding rumination, specifically, as a potential risk factor for mood disturbance when individuals stop exercising. The pattern of results in the current study lends support for a vulnerability-stress model for the development of depressive and anxiety symptoms in an exercise cessation paradigm. In this way, brooding rumination serves as an underlying cognitive vulnerability, which when combined with a 2-week period of exercise cessation leads to subsequent mood disturbance, as measured by POMS-Brief and BDI-II. This pattern of results supports this cognitive construct as a risk factor for the development of mood symptoms when individuals forgo their exercise routine.

Given that time was not included in the final model predicting BAI scores, the time-varying effect of brooding rumination on anxiety symptoms cannot be examined. A marginally significant main effect of brooding rumination on anxiety scores was found within the best fitting model, such that, collapsed across all time points, higher levels of brooding rumination may be predictive of greater anxiety scores as measured by the BAI. This result is in support with previously described literature, in which rumination is associated with not only depressive symptoms, but anxiety symptoms as well (for a review see Thomsen, 2006). Although findings regarding the association between rumination and negative affect other than depression have been mixed, some studies found rumination to be positively associated with anxiety symptoms in cross-sectional designs (Flett et al., 2002; Fresco, Frankel, Mennin, Turk, & Heimberg, 2002; Thomsen, Mehlsen, Christensen, & Zachariae, 2003) and in longitudinal studies (Garnefski, Kraaij, & Spinhoven, 2001; Nolen-Hoksema, 2000). Thomsen's review (2006) concludes that there appears to be an association between rumination and anxiety, with further research needed to verify this relationship. Of note, these studies examined rumination as one construct, and did not differentiate subscales/subtypes of rumination (e.g., brooding rumination vs. reflective pondering). Despite this difference, the current study is in line with Thomsen's (2006) recommendation, with the results suggesting that brooding rumination may be associated with anxiety symptoms in a sample of healthy exercisers during an exercise cessation protocol. Given the marginally significant results, and that this is the first study of its kind to assess brooding rumination in an exercise cessation paradigm, further research is needed to test this relationship.

Contrary to the hypothesis, no predictive relationship between dysfunctional attitudes or cognitive reactivity and mood disturbance was revealed during the exercise cessation protocol. More specifically, neither of these cognitive vulnerabilities showed a significant main effect or an interactive effect with time in prediction of any of the mood outcome measures. This is surprising, given that longitudinal studies have found higher levels of both of these constructs to be predictive of depressive symptoms, as well as depressive episode onset (Alloy et al., 2000; 2006; Iacoviello et al., 2006; Segal et al., 1999; 2006). Furthermore, prior studies have provided support for Beck's vulnerability-stress model, in which dysfunctional attitudes interact with stressful life events to predict future depressive symptoms (Alloy et al., 2006; Dykman & Johll, 1998; Hankin et al., 2004; Kwon & Oei, 1992; Lewinsohn et al., 2001).

There are a number of possible reasons for the non-significant results for dysfunctional attitudes and cognitive reactivity in this study. First, the abovementioned studies that found support for Beck's vulnerability-stress model with dysfunctional attitudes measured stressful life events via self-report measures (i.e., the Negative Life Events Questionnaire (Saxe & Abramson, 1987), the Life Events Schedule (Sandler & Block, 1979), and the Schedule of Recent Experiences (Holmes & Rahe, 1967)). In contrast, the two-week period of exercise cessation was considered as the stressor here, which may be inherently different than the stressful life events measured in previous studies (e.g., poor performance in work or school; interpersonal conflict with family, friends, romantic partners). This methodological difference may explain why the current study did not replicate previous findings for the predictive relationship between dysfunctional attitudes and depressed mood. Secondly, the exercise cessation "stressor" was expected, as participants were not blind to experimental condition (i.e., exercise maintenance vs. cessation), whereas this is not the case for many stressful life events experienced (e.g., sudden loss of job, death of loved one). Therefore, the confounding factor of predictability of the stressor may contribute to the differing results. As such, a vulnerability-stress model involving dysfunctional attitudes as the underlying cognitive vulnerability does not appear to generalize to an exercise cessation paradigm. Prior literature implying cognitive reactivity as a predictor of future depressive episodes has utilized samples of previously depressed patients treated to remission (Segal et al., 1999; 2006) and studied relapse and recurrence of episodes as outcomes, rather than first onsets of depression. The current sample has a proportion of participants who met criteria for a past Major Depressive Episode (16.7%), which is comparable to the lifetime prevalence of depression in the general population (16%; Kessler et al., 2003), but is largely comprised of never-depressed individuals. Therefore, the non-significant finding regarding cognitive reactivity may imply that this cognitive construct is predictive of future, but not first onset, episodes of depression. Future research is needed to replicate these results, both in never-depressed populations and in exercise cessation protocols.

5.3. Aim 3

The third aim was to examine the role of psychological self-report measures (i.e., motivation for exercise, exercise-related coping style, perceived impact of fatigue on one's life, emotion dysregulation, and beliefs regarding the personal benefits of exercise) on mood disturbance during a period of exercise cessation. To do this, analyses examined the main effects of these constructs, as well as their interactive effects with cognitive vulnerability variables on the mood outcome measures, with covariates from the primary analyses (e.g., time, cognitive vulnerability measures, time by cognitive vulnerability interactions) included in the models.

5.3.1. Aim 3a: Main Effects of Psychological Self-Report Measures

Congruent with the third hypothesis, fatigue severity, motivation for exercise, using exercise to cope with stress, and emotion dysregulation were identified as important factors in the development of mood symptoms during a period of exercise cessation, with the greatest support for fatigue severity as a predictor of depressive and anxiety symptoms. Results indicated that individuals who perceived that fatigue greatly impacts their life and functioning (i.e., higher scores on the Fatigue Severity Scale (FSS)), had higher baseline levels of depressive symptoms, as measured by the BDI-II, and a trend for higher baseline levels of anxiety, as measured by the POMS Brief-Tension subscale, which were maintained over the study protocol. These findings suggest that individuals who interpret fatigue as more impactful on their motivation, exercise, duties, or physical functioning, and as more interfering in the domains of family, work, or social responsibilities are at greater risk for depression and anxiety symptoms, above and beyond the effects of well-established cognitive vulnerability constructs and time in an exercise cessation paradigm. Although the BDI-II includes two items assessing low energy and fatigue, these items are distinct from the FSS, which is a subjective measure of the effects of fatigue on one's life. Therefore, these findings highlight the role of one's cognitive interpretation of the effects of fatigue and suggest that a greater degree of negative beliefs regarding the impact of fatigue on one's life puts individuals at greater risk for mood disturbance over an exercise cessation protocol. A significant main effect for FSS was also found in prediction of BAI scores; however, this effect was qualified by a FSS by brooding rumination interaction, described below. Taken as a whole, these results signify the importance of examining fatigue perceptions in the field of exercise cessation, such as examining fatigue severity in conjunction with outcome measures assessing changes in fatigue (e.g., POMS-Brief Fatigue subscale) over a period of exercise cessation.

Results from the current study additionally lend support for the Reasons for Exercising Inventory (REI)-stress/mood management subscale, the Coping Inventory for Stressful Situations (CISS)-exercise subscale, and the Difficulties in Emotion Regulation Scale (DERS) as important measures capturing constructs that serve as risk factors for mood disturbance in an exercise cessation paradigm. Findings from this study suggest that over an exercise cessation protocol, exercising for stress reduction and mood management purposes (i.e., higher scores on the REI-stress/mood management subscale) and a tendency to cope with stress via exercise (i.e., higher scores on the CISS-exercise subscale) puts individuals at risk for higher baseline anxiety and depression symptoms, respectively, as measured by the POMS Brief, with such elevations maintained over the study protocol. Individuals who use exercise for mood regulatory purposes, without this activity, may lack strategies that serve the same function, resulting in the increased depression and anxiety symptoms seen in these exploratory analyses. Prior research by Thome and Espelage (2004) supports an association between exercise-related coping via the CISS-exercise subscale and improved psychological health and decreased negative affect. Although exercise-related coping was examined in the context of engagement in physical activity vs. exercise cessation in their study, the authors' conclusion lends support to the interpretation that a barrier to this coping mechanism could result in the inverse relationship (i.e., an increase in mood disturbance).

Study results also suggest that higher levels of emotion dysregulation may be associated with increased baseline depression scores on the BDI-II, which are maintained over time. Although only marginally significant, this result suggests that emotion dysregulation may serve as a potential risk factor for mood symptoms over an exercise cessation protocol. This result can be interpreted in the context of the emotion dysregulation model for anxiety and mood disorders, which posits that difficulties in regulating negative emotions, combined with a lack of positive emotions, are central to such disorders (Hofmann, Sawyer, Fang, & Asnaani, 2012). According to this diathesis-stress model, a particular trigger combined with certain affective styles (e.g., appraisal of emotions as intolerable, resulting in avoidance of emotional experience) and emotion dysregulation results in the development of mood and anxiety disorders. This finding suggests the possible applicability of this model to an exercise cessation paradigm, such that in the context of discontinuation of one's exercise routine, emotion dysregulation may serve as a risk factor for the development of depression symptoms.

These analyses and results are exploratory in nature, as no study to date has examined any of these constructs in the context of exercise cessation. Therefore, readers are advised that the conclusions made should be interpreted with caution, with additional research needed to corroborate these results, and to ascertain the potential role of fatigue severity, exercising for stress reduction and mood management purposes, exercise-related coping, and emotion dysregulation (i.e., emotion dysregulation model) in exercise cessation paradigms. Nonetheless, this preliminary work expands upon prior exercise cessation research by beginning to identify psychological constructs that serve as risk factors for the development of depression and anxiety symptoms when individuals stop exercising, beyond the cognitive vulnerability constructs previously described.

5.3.2. Aim 3b: Moderating Effects of Psychological Self-Report Measures

Contrary to the fourth hypothesis, little support was found for the interactive effects of psychological self-report measures and cognitive vulnerability variables on the mood outcome measures. Final models in prediction of BDI-II, POMS Brief-Tension subscale, and POMS Brief-Depression subscale scores did not support the hypothesis that higher levels of cognitive vulnerability, combined with higher scores on the FSS, DERS, REI-stress/mood management subscale, or CISS–exercise subscale, places individuals at increased risk for depressive or anxiety symptoms during exercise cessation, beyond the main effects of these constructs. Therefore, these psychological self-report measures did not moderate the effect of cognitive vulnerability on mood outcome measures over a period of exercise cessation. Furthermore, as the time by psychological self-report measure interactions were not included in the final adopted models, it can be concluded that although higher levels on certain measures increase depression and anxiety scores at baseline (i.e., main effects observed for the FSS, DERS, REI-stress/mood management, CISS-exercise), that the rate of increase did not change over time. In other words, the increase in mood symptoms associated with higher levels of these psychological self-report measures was maintained over the entire study protocol, and a greater increase in symptoms was not observed during the two weeks of exercise cessation.

It is possible that the lack of support for the fourth hypothesis involving the moderating effects of psychological self-report measures may be explained by insufficient power to detect these effects. Models compared in these analyses included a range in the number of covariates entered into the equation, depending upon the number of psychological self-report measures that were found to be included in the best fitting model for the previous hypothesis. For example, in prediction of BDI-II scores, the least parsimonious model testing the fourth hypothesis included the time predictor and 11 covariates (i.e., the cognitive vulnerability variables, fatigue severity, emotion dysregulation, and their corresponding interactions). Despite having four time points and thus decreasing the sample size needed for effects to be detected, the modest sample size (N=36) may be too small to detect an interactive effect in a model with this many covariates included. It is possible that with a larger sample, significant psychological self-report by cognitive vulnerability interactions would be found, and further research is needed to confirm or contradict these results. Despite the small sample, it is also possible that the combination of high levels of cognitive vulnerability and high levels on these self-report measures do not put individuals at increased risk for depression and anxiety symptoms, beyond the main effects previously accounted for. With no prior research on these constructs in the exercise cessation field, the hypothesis was entirely exploratory in nature, with the validity of the non-significant results also important to consider.

The exception to this pattern of results was in prediction of BAI scores, such that the final adopted model included a significant interactive effect of fatigue severity by brooding rumination. This interaction implies that high levels of brooding rumination and high levels of fatigue severity put individuals at increased risk for anxiety symptoms, relative to individuals who scored low on either of the measures. Given that this model did not include a time predictor, this finding implies that collapsed across time points during an exercise cessation protocol, fatigue severity moderated the effect of brooding rumination on anxiety scores within this paradigm. It appears that having strong beliefs regarding the impact of fatigue on one's life, as well as a tendency to focus on one's symptoms of distress, specifically comparing that state to an unrealistic standard, predicted greater levels of anxiety. It is feasible that a cognitive bias or focus on the perceived functional impairment of fatigue on one's life (i.e., fatigue severity) would exaggerate the difference between one's perceived state and a desired state (i.e., brooding rumination), thus resulting in greater levels of anxiety experienced relative to individuals who did not hold either of these cognitive patterns. Particularly given that the effect of time is not included in this model, the moderating effects of fatigue severity on brooding rumination and anxiety outcomes should be examined in general populations, as well as in exercise cessation protocols.

5.4. Aim 4

The fourth aim was to examine the effects of baseline physical activity level (estimated as energy expenditure in MET-hours per week from exercise) on mood outcomes in an exercise cessation paradigm. Again the analyses were two-fold, such that the main effects of baseline physical activity level, as well as the interactive effects of baseline physical activity level and cognitive vulnerability constructs on the mood outcome measures were examined, with covariates from the primary analyses (e.g., time, cognitive vulnerability measures, time by cognitive vulnerability interactions) included in the models.

5.4.1. Aim 4a: Main Effects of Baseline Physical Activity Level

Contrary to the fifth hypothesis, there was no significant main effect of baseline physical activity level in prediction of any of mood outcome measures. These results indicate that in the current sample, baseline physical activity level was not predictive of depression or anxiety symptoms (i.e., BDI-II, BAI, POMS Brief-Depression and Tension subscale scores) over an exercise cessation protocol.

Although there was a substantial range in baseline energy expenditure (18.2-94 MET-hours/week) across participants, it is possible that the inclusion and exclusion criteria for the study limited variability in this construct, and therefore the possibility of detecting a significant effect. More specifically, participants were required to meet American College of Sports Medicine guidelines for physical activity, defined as a minimum of 30 minutes of moderate-intensity aerobic physical activity 5 days per week, or 20 minutes of vigorous-intensity aerobic physical activity 3 days per week (Haskell et al., 2007). By using this guideline, the current study thus restricted the inclusion of exercising individuals who would be at the lower range of baseline energy expenditure. Additionally, individuals who were considered to be at risk for exercise dependence, as measured by the Exercise Dependence Scale (Hausenblas & Symons Downs, 2002), were excluded from participation. Such individuals are likely high frequency and intensity exercisers with items designed to capture increased time spent exercising and increased exertion during exercise (e.g., “A great deal of my time is spent exercising,” “I continually increase my exercise duration to achieve the desired effects/benefits,” and “I am unable to reduce how often I exercise”). It can be implied that this exclusion criterion limited the inclusion of higher levels of baseline energy expenditure in the study sample. Future studies with less restrictive inclusion/exclusion criteria are needed to examine whether these results hold, or if a greater range in baseline physical activity produces differing results.

Alternatively, these results may indicate a truly non-significant effect, in which case mood symptoms develop in regular exercisers when individuals stop exercising, and this is not dependent on their physical activity level at baseline. This suggests that it is not the relative amount of change in exercise, measured as energy expenditure, from pre- to during exercise cessation, but rather the absolute discontinuation in exercise, as well as the effects of cognitive vulnerability constructs, that influence subsequent mood symptoms. Only one prior study examined the effect of baseline physical activity on psychological outcomes post-exercise cessation. This observational study by Johnston and Carroll (2000) assessed the impact of injury on psychological well-being in regular exercisers or athletes going through rehabilitation recovery. Although the outcome measures were different, these authors found similar results, such that amount of time per week engaged in sports or exercise was not associated with depression or anxiety symptoms, as measured by the POMS. A significant association was found between confusion and baseline physical activity, with greater involvement in exercise prior to injury associated with increased confusion mid-way and post-rehabilitation. Given the limited amount of research examining the effects of baseline physical activity on mood outcomes during exercise cessation, further studies are needed to replicate these results. Additionally, the association between baseline physical activity and mood disturbance should be examined with different outcome measures (i.e., confusion) to fully assess the relationship between this construct and psychological well-being during periods of exercise cessation.

5.4.2. Aim 4b: Moderating Effects of Baseline Physical Activity Level

Study results indicate that higher levels of brooding rumination and lower levels of baseline physical activity were predictive of depressive and anxiety symptoms as measured by the BDI-II and BAI over an exercise cessation protocol. In prediction of BDI-II scores, the final model that included time and cognitive vulnerability variables as covariates found that higher levels brooding rumination combined with lower levels of baseline physical activity was associated with the greatest depressive symptoms, above and beyond the main effect of brooding rumination. Furthermore, individuals with lower levels of brooding rumination and higher levels of baseline physical activity were the most resistant to depressive symptoms over an exercise cessation protocol. In prediction of BAI scores, it was found that collapsed across time points, individuals with both higher levels of brooding rumination and lower levels of baseline physical activity were at the greatest risk for anxiety symptoms, qualifying the main effect found for brooding rumination (Figure 6). This result implies that in the exercise cessation protocol, brooding rumination served as a risk factor for anxiety symptoms among individuals with relatively lower levels of baseline physical activity.

These findings are surprising in that they are contrary to the sixth hypothesis in which higher levels of baseline physical activity combined with higher levels of cognitive vulnerability were expected to be associated with greater mood symptoms. This pattern of results did not generalize to the Depression and Tension subscales of the POMS Brief, as significant cognitive vulnerability by baseline physical activity interactions were not found in prediction of these scores.

One potential explanation for the results involves the longstanding positive mood effects from exercise. It is possible that individuals who exercise to a greater degree create a “store” of the positive psychological benefits gained through exercising, whereas individuals with lower levels of baseline physical activity do not have this backup in place. Individuals with high levels of brooding rumination were at increased for depression and anxiety symptoms, therefore high brooding combined with low levels of previously accumulated psychological benefits (i.e., low baseline physical activity) could explain the greatest increase in depression and anxiety symptoms within this subsample of participants. Conversely, low levels of brooding rumination and higher baseline activity, and thus a greater store of psychological benefits in place, could result in lower levels of symptoms, which is supported by BDI-II results, specifically. This potential explanation assumes that the psychological benefits of exercise are long lasting, an assumption with mixed backing. In a review of the impact of exercise on positive affect by Reed and Ones (2006), positive affect increases immediately (0-5 minutes) after exercise, with smaller effects over time. However, results also suggest that this pattern may not hold for all settings, and therefore the authors recommend further examination of moderators of post-exercise affect trajectories. Relatedly, some studies have shown longer lasting effects (i.e., 1 hour; Cox, Thomas, & Davis, 2001; Daley & Welch, 2004) from bouts of acute exercise. These studies support the plausibility of more longstanding effects of exercise on positive affect, with future research needed to examine the effect of exercise (acute and regular) on outcomes days and weeks post-exercise. Additionally, to further test this hypothesis, measures of positive affect should be administered in conjunction with assessment of baseline physical activity in exercise cessation paradigms.

5.5. Clinical Implications

These study results expand upon prior exercise cessation literature by determining cognitive vulnerability constructs (i.e., brooding rumination), psychological self-report variables (i.e., fatigue severity, emotion dysregulation, exercising for stress reduction and mood management purposes, a tendency to cope with stress via exercise), and baseline physical activity levels at the low end of meeting the ACSM recommendations that serve as potential mechanisms and moderators underlying the well-documented increase in mood symptoms following a period of exercise withdrawal. This information is important in that it serves to help identify individuals who are at greatest risk for the development of depression and anxiety symptoms when they forgo their exercise routine, with clinical implications for patient assessment, prevention and treatment efforts.

Results from the primary analyses have the greatest clinical implications for improved patient care. By integrating cognitive vulnerability research from the unipolar depression field with exercise cessation literature, the current study allowed for the identification of the individuals who may be at increased risk for depression and anxiety symptoms based on the well-established construct of brooding rumination. Given that rumination is considered trait-like (vs. state-like), measurement of this construct prior to known periods of exercise cessation (e.g., in the case of pregnancy, surgery, hospitalization, new job/change in lifestyle) would meaningfully identify individuals who are most likely to experience depressive and anxiety symptoms when their exercise is ceased (Bagby et al., 2004; Just & Alloy, 1997; Kuehner & Weber, 1999; Nolen-Hoeksema et al., 1993; 1994). Thus, these results inform assessment efforts by suggesting that the RRS should be used in clinical practice by psychologists and medical professionals to identify individuals to whom prevention and treatment efforts should be directed. Given that the RRS is a 22-item self-report measure, administration is feasible in a variety of general medical settings (e.g., primary care offices, rehabilitation centers) by a range of providers.

Results from the primary aim highlight the utility of developing and testing interventions to target brooding rumination specifically. A recent review by Querstret and Cropley (2013) assessed the efficacy of treatments for anxiety and depression in reducing rumination and worry. Of the 19 studies reviewed, 10 reported results on rumination, measured by the RRS, with treatments involving mindfulness-based therapy, relaxation-focused therapy, concreteness training (i.e., training individuals to become more specific and concrete in their thinking), and cognitive-behavioral therapy (CBT) interventions. These authors found support for mindfulness-based and cognitive-behavioral interventions in reducing rumination, suggesting that changing the way in which individuals respond to ruminative thoughts (i.e., through mindfulness techniques) or challenging the thoughts or beliefs involved in ruminative thinking patterns (i.e., through cognitive restructuring or concreteness training) is effective in reducing rumination. One such study by Watkins and colleagues (2011) tested the effectiveness of rumination-focused CBT in treatment-resistant depression, and found reductions in rumination to be mechanistic of the treatment effects in reducing depressive symptoms. Rumination-focused CBT is a 12-session CBT protocol tailored specifically to address the function of rumination through functional analyses and behavioral experiments. The current study results suggest the application of these interventions as prevention or treatment efforts for individuals deemed at risk for increased depression and anxiety symptoms, based on higher baseline levels of brooding rumination. A recent study tested the utility of treatments aimed at reducing rumination and worry (termed negative repetitive thinking) in a sample of individuals who scored high on these two constructs but did not meet diagnostic criteria for MDD or GAD (Ehring, Topper, Watkins, & Emmelkamp, 2015). Results indicated that CBT aimed at targeting this thought process resulted in reduced rumination and worry at post-treatment, as well as lower anxiety and depressive symptoms at follow-up 1 year later. This study suggests the effectiveness of preventative efforts to reduce subsequent psychopathology in individuals deemed at high risk for negative repetitive thinking, including high levels of rumination. The effectiveness of the abovementioned interventions in reducing rumination, the mechanistic effects of rumination in treatment efficacy, and the initial research on preventative interventions for individuals high in rumination and worry, suggests the possibility of preventing and/or decreasing mood symptoms during periods of real-life exercise cessation with these interventions.

Although additional studies are needed, results from exploratory analyses also suggest the potential role of fatigue severity, exercising for stress reduction and mood management purposes, exercise-related coping, and emotion dysregulation as risk factors for mood disturbance in this paradigm. Taken as a whole, these results could inform prevention efforts for higher risk individuals who are faced with a period of exercise cessation. These findings suggest the potential for implementing cognitive interventions aimed at challenging overly negative beliefs regarding the impact of fatigue on one's life, expanding one's coping strategies to include other dimensions beyond exercise (e.g., task- or emotion-related coping), and implementing emotion regulation, cognitive, and behavioral strategies aimed at better emotion regulation and mood management as prevention efforts for individuals who score high on the respective measures (i.e., FSS, DERS, CISS-exercise subscale, REI-stress/mood management subscale). Intervening via these means prior to a period of foreseen exercise cessation may reduce the relative increase in depressive and anxiety symptoms expected based on these risk factors and promote better psychological health both in the short- and long-term.

Finally, the exploratory analyses examining the moderating effects of baseline physical activity level on brooding rumination and mood outcome measures suggest consideration of activity level for prevention and treatment efforts. Replication of results is needed before definite conclusions can be drawn, however, the presented findings suggest that in addition to assessing brooding rumination, gathering information about an individual's regular exercise routine may help to determine risk for the development of depression and anxiety symptoms in the context of ceased exercise. When assessing for brooding rumination in clinical and medical practices in the context of foreseen periods of exercise cessation (e.g., pregnancy, surgery, hospitalization, new job/change in lifestyle), it may be incrementally beneficial to identify individuals who are physically active but engage in lower levels of exercise.

5.6. Limitations

Limitations of this study should be taken into account when interpreting the findings. First, the study sample is relatively small (*N*=36), and therefore replication of results is needed to verify the findings presented here. Furthermore, the sample consists of primarily White, single participants with the majority having a college or graduate degree, consistent with the Burlington, VT demographics. Therefore, the generalizability of the results to the general population is not known, and further research with different samples is needed to determine whether the findings hold in other racial/ethnic groups, with non-singles, and lower education levels. Despite this limitation, is it important to note that the small sample size is within the range used in prior experimental exercise cessation paradigms, with samples ranging from *N*=10 (Mondin et al., 1996) to *N*=40 (Berlin et al., 2006).

A second limitation is participants' awareness of the general research question of this study, which is inherent in the study design and protocol. Participants were given the explanation during the informed consent process that this research aims to examine the effects of exercise cessation on mood. Given the lack of manipulation in the consent process, as well as the face validity of the mood outcome measures administered at each time point, it can be assumed that participants were aware of the expected decline in mood over the exercise cessation protocol. For these reasons, it is possible that an observer-expectancy effect was present in the current study, such that in assuming the study aimed to detect a worsening in mood, participants may have rated depression and anxiety symptoms as increased over the exercise cessation phase of the study. Although this is possible and important to consider, it is also worth noting that time between assessments ranged from one to two weeks, and therefore it seems unlikely that participants would remember their responses on measures over that duration of time, which would be necessary to report a worsening effect of mood over the study protocol. Furthermore, although participants were aware of the examination of mood, they were not privy to a priori hypotheses involving cognitive vulnerability, psychological self-report measures, or baseline physical activity level, and therefore their responses on these measures would likely not be affected by a potential observer-expectancy bias.

A third limitation involves the data derived from the ActiGraph wGT3X activity monitor used to assess adherence to the exercise cessation protocol. As previously reported, although the majority of participants had valid accelerometer data for $\geq$ 85% of both study phases, which is considered to be a substantial proportion of the 4-week study protocol, there are periods of time in which participants did not wear the activity monitor, or during which the equipment malfunctioned. This time in which physical activity of participants could not be captured is considered a limitation of the study and does not allow us to determine full adherence to the exercise cessation protocol (i.e., it is possible that participants could have purposefully removed their activity monitors and engaged in exercise during the exercise cessation phase). It should be noted, however, that the amount of time participants wore the activity monitors during the maintained exercise phase and the exercise cessation phase was relatively similar (on average 86% and 79.8%, respectively), implying that intentional removal of the device for exercise during the latter phase does not seem likely. Nonetheless, future studies are needed to assess the extent to which participants wear wrist-worn activity monitors in four-week research studies, in general, as well as in the context of exercise cessation paradigms. Such research will shed light on exercise cessation protocols and allow for more accurate examination of adherence to experimental designs. Additionally, such research may potentially provide information on the associations between particular variables measured (e.g., cognitive vulnerability, coping style) and a perceived need to exercise (i.e., deviation from the protocol), which may be informative of further risk factors for emotional distress during periods of exercise cessation.

A fourth limitation involves the validity of data gathered by the wrist-worn ActiGraph wGT3X+ activity monitors used in the current study. When worn on the hip, these accelerometers provide validated estimates of physical activity, however, studies are currently lacking regarding the effectiveness of the wrist-worn device in providing accurate physical activity data, with research currently underway to create new algorithms and cut points to interpret wrist-worn data. Although accelerometers worn on wrists have been reported as more comfortable and easier to wear, and therefore may increase adherence to wearing the device, given that the activity monitors were worn on participants' wrists (vs. hips), the accelerometer data should be interpreted with caution. This data derived is considered a limitation of the study, as it cannot be inferred that energy expenditure estimates and physical activity level information is fully accurate. Given this limitation, the current study used derived activity counts from the activity monitors as the variable of interest when comparing between the maintained exercise and exercise cessation phases. Research on the wrist-worn ActiGraph wGT3X+ found activity counts moderately correlated with these waist-worn devices, and thus this serves as an appropriate estimate of adherence to the exercise cessation protocol (Mahar, Rowe, & Mahar, 2013).

5.7. Future Directions

Despite the abovementioned limitations, the current study contributes to the exercise cessation field by examining potential mechanisms and moderators underlying the increase in mood symptoms previously documented when individuals stop exercising. As suggested above, given that this study is the first to examine these constructs in an exercise cessation paradigm, future studies are needed to replicate these findings, using larger and more generalizable samples. This is particularly important for the results involving the self-report psychological and baseline physical activity variables, as these analyses are exploratory in nature and do not have the same research backing relative to the well-established cognitive vulnerability constructs examined in the primary hypotheses.

As previously mentioned, given the inclusion criteria involving minimum amount of exercise needed to be enrolled, and exclusion criteria involving individuals considered at risk for exercise dependence, a limited range in baseline physical activity level may have been created for participants enrolled in the current study. Future research is needed with samples which have baseline physical activity levels above and below the included range to determine if these results generalize to different populations. For example, testing these hypotheses in samples of athletes and long-distance runners, as well as in low exercise but non-sedentary populations (i.e., below ACSM physical activity guidelines) will determine if a similar pattern of results holds in differing samples. Such research will allow for conclusions to be made about examined mechanisms and moderators involved in the development of mood symptoms during periods of exercise cessation across varying samples, which are considered to be relatively distinct from the generally healthy, exercising population examined here.

In order to increase clinical implications of exercise cessation research, future studies should create designs that further imitate real-life situations in which exercise is not possible or greatly decreased. One way to do this is to examine longer periods of exercise cessation beyond the two-week period included in the current study. As many instances would necessitate ceasing one's exercise routine for longer than two weeks, future experimental studies should include periods of exercise cessation up to a month in length in order to examine the effects of mood, as well as the associations between mechanisms and moderators on depression and anxiety symptoms, over longer periods of time. In this way, exercise cessation studies will be more representative of individuals' experiences when needing to stop exercising for reasons such as injuries, surgeries, hospitalizations, and pregnancies. Secondly, it may be informative for studies to randomly assign participants to varying exercise cessation period lengths (e.g., 5 days, 1 week, 2 weeks, 3 weeks) with participants unaware of when their protocol ends in order to better assess the effects of exercise cessation on mood without the potentially confounding factor of predictability regarding when participants will be able to return to their exercise routine.

Finally, the exercise cessation literature should examine the effect of varying levels of decreased exercise or exercise cessation on mood in order to determine if a dose-response relationship is present in this paradigm. Future studies are needed to determine if a substantial decrease in exercise vs. full exercise cessation produces the same deterioration in mood. For example, future studies in which participants are randomized to a small decrease in exercise (e.g., a 25% decrease) vs. a large decrease in exercise (e.g., a 75% decrease) vs. full exercise cessation will elucidate the relationship between the proportion of baseline exercise removed and mood outcome. Such findings will have clinical implications in determining when, and potentially at what level, prevention and intervention efforts are needed, based on the change in depression and anxiety symptoms seen at varying levels of decreased exercise. The ultimate goal of this work would be to create general cut-points for clinicians across medical fields involving the potential for decreased exercise to impact mood, with recommendations for gathering further information on risk factors (e.g., brooding rumination), and considering potential prevention and intervention efforts for patients.

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