WORKING IT OUT: ACUTE EXERCISE TO COMBAT ANXIETY, DEPRESSION, AND IMPROVE PSYCHOLOGICAL WELL-BEING IN INDIVIDUALS LIVING WITH PTSD

BY

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DISSERTATION

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ABSTRACT

While a relatively new area of study, current literature shows exercise interventions to be highly successful at reducing symptoms of Post-Traumatic Stress Disorder (PTSD) and comorbid psychological conditions (e.g., anxiety & depression). **Purpose:** Examine the acute effects of a bout of moderate intensity continuous aerobic exercise (MIA) and a bout of high-intensity interval exercise (HIIE), relative to a no-exercise sedentary control (SED), in participants with subsyndromal PTSD. **Methods:** Participants [*N*= 24, 15 females; age (*M* ± *SD*); 25.9 ± 9.2 yrs; Estimated VO_{2peak} (*M* ± *SD*); 34.6 ± 10.2 $ml \cdot kg^{-1} \cdot min^{-1}$] completed each of three randomly ordered 35-min conditions (HIIE, MIA, SED), followed by a 40-minute recovery/monitoring period. Subsyndromal PTSD was defined as having at least one symptom in each of the major DSM-5 clusters for PTSD. Affect (Energy, Tiredness, Tension, Calmness), State Anxiety, and Depression were assessed before (Pre), immediate after (Post0), 20-minutes after (Post20), and 40-minutes after (Post40) each condition. Exercise enjoyment was assessed immediately after each condition (Post0), and in-task affective valence was assessed every 5-minutes during MIA and SED, and after each set of exercise and rest during HIIE. **Results:** Anxiety and Depression were significantly reduced following all conditions, with larger effects observed for both HIIE and MIA relative to SED (although not significant). Post exercise enjoyment was not different between HIIE and MIA, but both were enjoyed more relative to SED. While in-task affective valence was significantly less positive during HIIE relative to both MIA and SED, and affective valence was significantly less positive during MIA relative to SED, affective valence was not different between conditions at Post40. All participants experienced a significant increase in affective valence at Post40 relative to Pre. Energy was significantly increased Post HIIE and MIA, while Energy was significantly decreased post SED. Additionally, Tension was significantly decreased and Calmness significantly increased by 40 minutes Post all conditions. **Conclusion:** This study is the first to assess the acute changes in psychological outcomes to various modes of exercise in individuals living with subsyndromal PTSD. Overall, both exercise conditions were well tolerated and significantly reduced anxiety, depression, and tiredness, while also significantly increasing energy and affective valence. With emerging evidence on the effectiveness of HIIE, this study gives ample evidence to explore a longitudinal study on HIIE effects within a population living with PTSD.

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION 1

CHAPTER 2: LITERATURE REVIEW 6

CHAPTER 3: RESEARCH METHODS 32

CHAPTER 4: RESULTS 47

CHAPTER 5: DISCUSSION 67

REFERENCES 77

CHAPTER 1

INTRODUCTION

Mental health disorders are increasingly prevalent in today's society. According to DSM-IV/World Health Organization World Mental Health Composite International Diagnostic Interview (WHM-CIDI) guidelines, 46.4% of Americans (aged 18 or older) have suffered from a mental health disorder (Kessler et al., 2005). Specific interest has focused on anxiety and mood disorders. From 1994 to 2005, there was an increase in lifetime prevalence rates of anxiety from 24.9 to 28.8 percent, and an increase from 14.7 to 20.8 percent lifetime prevalence of mood disorders (Kessler et al., 1994; 2005). According to DSM-IV criteria, anxiety is a label referring to a wide variety of disorders [e.g., panic, agoraphobia, social phobia, generalized anxiety, post-traumatic stress (PTSD)], and while each has distinct characteristics, many of these disorders share symptoms and treatments. Of particular interest is whether exercise can be an effective treatment. Physical exercise has been shown to significantly reduce generalized anxiety and anxiety symptoms, especially in individuals with elevated anxiety levels (Petruzzello, Landers, Hatfield, Kubitz, & Salazer, 1991). Additionally, a recent review and meta-analysis highlights the benefits of exercise in individuals with severe mental illness (Vancampfort et al., 2017), and reviews have shown exercise significantly reduces depression beyond a placebo effect (Cooney, Dwane, & Mead, 2014).

Given the demonstrated and potential utility of exercise in treating some anxiety disorders (e.g., panic disorder, generalized anxiety disorder; Stonerock, Hoffman, Smith, & Blumenthal., 2015) and that PTSD shares many commonalities with and was, until the recently released DSM-5, considered an anxiety disorder, it would be instructive to determine whether, and to what extent, exercise might be effective in decreasing symptoms of anxiety and depression and increasing psychological well-being in individuals living with PTSD. Additionally, as many as 84.4 percent of patients living with PTSD also suffer from major depressive disorder (MDD; Spinhoven, Penninx, van Hemert, de Rooij, & Elzinga, 2014). With the known beneficial effect exercise has on depression, exercise could be used to reduce comorbid mental disorders of PTSD. Not only is PTSD a significant mental health concern, but it also increases risk of significant declines in health-related quality of life. Individuals with greater PTSD symptoms (i.e., number and/or severity) have elevated risk for general health symptoms and medical conditions, and poorer health-related quality of life (Pacell, Hruska, & Delahanty, 2013). Spitzer et al. (2009) found that PTSD was significantly associated with increased incidence of cardiovascular and pulmonary disease, and individuals with PTSD are less likely to be physically active. Even without a potential beneficial effect on PTSD symptoms, physical activity interventions seem warranted to increase quality of life and overall health in individuals living with PTSD. Germane to the present study (and see below), while the effects of exercise on PTSD remain unclear, exercise effects on anxiety have been well documented. Specifically, a recent meta-analysis of randomized controlled trials (RCTs) indicated that acute exercise significantly decreases anxiety (Ensari, Greenlee, Motl, & Petruzzello, 2015). This is of specific interest as individuals with PTSD also suffer from increased anxiety (Keane, 2014). It thus seems essential to understand exercise-induced changes in anxiety and anxiety symptoms (i.e., hallmark features of PTSD) among those living with PTSD.

While there are well-established, empirically supported treatments for PTSD, treatment outcome data suggest that more than one-third of individuals remain symptomatic after receiving an empirically supported treatment (Cigrang et al., 2011). Additionally, psychotherapy trials for PTSD routinely show dropout rates that range from 19-27% (Hembree et al., 2003). This level of treatment response suggests individuals with PTSD may benefit from alternative treatment options. Applying exercise interventions for PTSD has important advantages given the demonstrated impact of exercise on high anxiety sensitivity, affective state, social withdrawal, and avoidance of feared bodily sensations (Asmundson et al., 2013)—all of which are important PTSD intervention targets. Additionally, a recent review has shown exercise to be effective in significantly reducing depression and improving overall health and quality of life within otherwise healthy as well as diseased populations (Knapen, Vancampfort, Morien, & Marchal, 2015). Systematic reviews, meta-analyses, and individual studies have shown exercise is an effective treatment for depression in individuals of all ages, and across multiple modes of exercise (Dunn, Trivedi, & O'Neal, 2001; Josefsson, Lindwall, & Archer, 2014; Rhyner & Watts, 2016), and regular exercise appears to protect against relapse to previous levels of depression (Babyak et al., 2000).

Given the above information, exploration of exercise interventions to decrease symptom severity and improve quality of life and overall health within individuals diagnosed with PTSD seems warranted. However, there has been very little research examining the viability of exercise to treat individuals with moderate to severe PTSD symptoms. Of the 6 studies directly assessing exercise and PTSD, all show significant decreases in PTSD severity and all but one shows beneficial effects on anxiety and depression measures. Most of the literature has examined only aerobic exercise effects on PTSD (i.e., 5 of 6), with the remaining study using both resistance and walking exercise (Rosenbaum, Sherrington, & Tiedemann, 2014). Further, no research has examined affect and enjoyment following an acute bout of exercise, and as such, no research has examined affective responses to various modes of exercise to treat/improve quality of life in individuals living with PTSD. This is of vital importance as other treatment options for PTSD have shown high dropout rates. Determining the mode of exercise that will maximize affect and enjoyment within individuals with PTSD may help increase adherence rates to longitudinal exercise interventions. Further, exploring the effects of an acute bout of exercise on PTSD would be essential in providing individuals with immediate, short-term, and cost-effective relief of direct and indirect symptoms. It may be that acute exercise can be used as a daily self-regulatory technique for mood, anxiety, and depression, with the long-term goal of stacking these short-term benefits to have a lasting and profound effect on PTSD symptomology.

The purpose of the present study was to examine, in a sample of individuals with PTSD-related symptoms: (a) the feasibility of implementing an acute bout of moderate intensity continuous aerobic exercise (MIA) and high-intensity interval exercise (HIIE) in individuals with PTSD-related symptoms; (b) whether an acute bout of exercise reduces anxiety, depression, and improves affective valence in individuals with PTSD-related symptoms more than a no-exercise control condition; and (c) how an acute bout of HIIE compares with more "traditional" MIA and a no-exercise control in such psychological changes. The overall aims of the project were to show that exercise is a safe, viable option for individuals living with PTSD-related symptoms, determine the mode of exercise that produces the most favorable affective and enjoyment responses, and importantly, to demonstrate that an acute (i.e., single) bout of exercise can reduce symptoms of co-morbid psychological disorders (e.g., anxiety & depression) in individuals with PTSD-related symptoms.

CHAPTER 2

LITERATURE REVIEW

Post-Traumatic Stress Disorder (PTSD)

PTSD has been classified as its own mental disorder in the Diagnostic and Statistical Manual of Mental Disorders (5th revision; DSM-5; American Psychiatric Association, 2013). Whereas it used to be classified as an anxiety disorder, PTSD falls under a new chapter on Trauma and Stress related disorders. Diagnosis of PTSD is determined by presence of eight specific criteria. First, an individual was exposed to a traumatic event (i.e., death, threatened death, actual or threatened serious injury, or actual or threatened sexual violence; Criterion A). An individual must show symptoms of intrusion/re-experiencing of the traumatic event (i.e., Criterion B), avoidance of stimuli associated with the event (i.e., Criterion C), negative alterations in cognitions and mood (i.e., Criterion D), and negative arousal/reactivity associated with the traumatic event (i.e. Criterion E; American Psychiatric Association, 2013). In addition, the disturbances caused by Criteria B, C, D, and E must persist for more than one month (i.e., Criterion F), cause clinically significant distress or functional impairment (i.e., Criterion G), and these disturbances must not be due to medication, substance abuse, or other illness (Criterion H; American Psychiatric Association). In order for a full diagnosis of PTSD, according to the DSM-5 diagnostic material, individuals must experience a traumatic event in one or more specific ways, exhibit one or more specific intrusion/re-experiencing symptoms, show one or more specific avoidance behaviors, exhibit two or more specific alterations in cognition/mood, and exhibit two or more alterations in arousal/reactivity (see Table 1; American Psychiatric Association).

Table 1
Specific Symptoms for Each Given Criteria of DSM-5 Diagnosis of PTSD

Criterion	Symptoms
A1	Directly experiencing the traumatic event
A2	Witnessing, in person, the event as it occurred to others
A3	Learning that the traumatic event occurred to a close family member or friend
A4	Experiencing repeated or extreme exposure to aversive details of the traumatic event
B1	Recurrent, involuntary, and intrusive distressing memories of the traumatic event
B2	Recurrent distressing dreams in which the content and/or effect of the dream are related to the traumatic event
B3	Dissociative reactions in which the individual feels or acts as if the traumatic event was recurring
B4	Intense or prolonged psychological distress at exposure to internal or external cues that symbolize or resemble an aspect of the traumatic event
B5	Marked psychological reactions to internal or external cues that symbolize or resemble an aspect of the traumatic event
C1	Avoidance of or efforts to avoid distressing memories, thoughts, or feelings about or closely associated with the traumatic event
C2	Avoidance of or efforts to avoid external reminders that arouse distressing memories, thoughts, or feelings about or closely associated with the traumatic event
D1	Inability to remember an important aspect of the traumatic event
D2	Persistent and exaggerated negative beliefs or expectations about oneself, others, or the world
D3	Persistent, distorted cognitions about the cause or consequences of the traumatic event that lead the individual to blame himself/herself or others.
D4	Persistent negative emotion state
D5	Markedly diminished interest or participation in significant activities
D6	Feelings of detachment or estrangement from others
D7	Persistent inability to experience positive emotions
E1	Irritable behavior and angry outbursts typically expressed as verbal or physical aggression toward people or objects
E2	Reckless or self-destructive behavior
E3	Hypervigilance
E4	Exaggerated startle response
E5	Problems with concentration
E6	Sleep disturbance

Table adapted from the American Psychiatric Association (2013).
Note. Criteria A4 cannot be due to media, television, movies, or pictures unless in a professional setting.

PTSD symptoms are much more prevalent in members of the military and National Guard/Reserve (12.1-13.3%) than in the general population (2.3-2.9%; Rosellini et al., 2015). Prevalence estimates of combat-related PTSD in veterans of Operation Iraqi Freedom and Operation Enduring Freedom have been reported to range from 3.7% to 17.1% (Hoge, Auchterlonie, & Milliken, 2006; Seal, Bertenthal, Miner, Sen, & Marmar, 2007). Other findings report prevalence rates for military veterans at 15.2% for men, and 8.5% for women meeting full PTSD criteria, with an additional 11.1% of males and 7.8% of females showing dysfunctional PTSD symptoms without meeting full criteria (Jordon et al., 1991). Among civilians, the National Comorbidity Survey (2005) estimated that 3.6% of men and 9.7% of women meet criteria for full PTSD, while other studies estimate overall prevalence of PTSD at 6.8% for all adults (Kessler et al., 2005). Steenkamp, Nash, and Litz (2013) have noted that "The enormous personal, societal, institutional, and economic costs associated with military-related PTSD create a compelling need for rigorously tested, evidenced-based prevention programs that draw on and expand existing scientific knowledge of PTSD prevention." (p. 511). As such, there are numerous empirically supported treatments for individuals living with PTSD.

Current PTSD treatments focus primarily on psychotherapy and medication (i.e., pharmacology). Cognitive behavioral therapy (CBT) has been highly effective in reducing symptoms of PTSD in combat and noncombat related trauma. Bradley, Greene, Russ, Dutra, and Westen (2005) conducted a meta-analysis on PTSD and CBT. Results indicated that 67% of participants who completed CBT no longer met full PTSD criteria. While no studies in the meta-analysis included individuals with comorbid disorders (see below), the efficacy of CBT is highly significant for compliers. Further, the overall effect size for active treatment versus control groups was 1.11, indicating psychotherapy significantly improves (i.e., decreases) PTSD symptoms (Bradley et al.). Cigrang et al. (2015) implemented a brief CBT program in 24 active military members with deployment-related PTSD. Again, results indicated significant reductions in PTSD severity from pre to post-treatment, which was maintained at 6 and 12-month follow-up assessments. A recent review on exposure therapy to treat PTSD concluded CBT is highly effective in reducing PTSD symptoms as well as some comorbid disorders (Rauch, Eftekhari, & Ruzek, 2012). Along with reducing PTSD symptoms directly, psychotherapy has also been shown to reduce other mental disorders associated with PTSD. Specifically, CBT has been shown to significantly reduce symptoms of anxiety, depression, guilt, and anger (Cahill et al., 2003; Foa et al., 2005). However, even with all the benefits of therapy, it is important to note that over one-third of the individuals receiving CBT remain symptomatic (Cigrang et al.). Additionally, overall compliance with CBT is low with dropout rates reported at over 40 percent (Fernandez, Salem, Swift, & Ramtahal, 2015), and a large percent of individuals not seeking active treatment for PTSD (estimated around 50%; Hoge, 2011).

There is also some concern that psychotherapy treatments for PTSD are less effective in military populations and men. Bradley et al. (2005) conducted a multi-dimensional meta-analysis on psychotherapy treatments for PTSD among veterans and non-veterans. Results indicated a significantly smaller treatment effect in veterans (d= 0.8) than in non-veterans (d= 1.82; Bradley et al.). While significant reductions in PTSD symptoms were observed across both samples, it appears both males and veterans would benefit from alternative treatment options.

As mentioned above, therapy [e.g., Prolonged Exposure (PE)] has been consistently shown to decrease PTSD symptoms. As such, research was conducted to see if additional psychotherapy techniques could further enhance benefits. One study assigned 87 individuals with PTSD to 10 sessions of PE, cognitive restructuring, PE plus cognitive restructuring, or relaxation only. Results indicated significant improvements across all conditions, with larger effects observed in the three active conditions and no difference in PTSD symptom reduction between PE, cognitive restructuring, or the combination condition (Marks, Lovell, Noshirvani, Livanou, & Thrasher, 1998). These results have been supported by Foe et al. (2005), who found PE combined with cognitive restructuring did not offer any additional benefits on PTSD symptoms beyond PE or cognitive restructuring alone. Foa et al. (1999) compared PE, Stress Inoculation Training, and a combination of the two on PTSD symptom reduction over 9, bi-weekly sessions. Results indicted no further reduction of symptoms with a combination of therapy. In fact, PE only participants achieved the largest improvements in functioning. It appears that combining multiple psychotherapy techniques does not provide additional benefit in reducing PTSD symptoms. This could be due to the fact that various psychotherapy methods work through similar or identical mechanisms. Therefore, exploring alternative treatments, specifically treatments that work through different mechanisms, could provide additional relief of symptoms when combined with psychotherapy.

In addition to psychotherapy, medication is a common treatment for PTSD. Antidepressants and anti-anxiety medication are often prescribed for PTSD. Krystal et al. (2011) conducted a 6-month, randomized, double-blind, placebo-controlled study on 296 veterans diagnosed with military PTSD. Results indicated no significant differences in the Clinician-Administered PTSD Scale, the Montgomery-Asberg Depression Rating Scale, Hamilton Anxiety Scale, or quality of life (assessed via SF-36V; Krystal et al.) between active medication and placebo conditions. Further, patients assigned to risperidone (i.e., anti-anxiety medication) experienced a significant increase in weight, fatigue, drowsiness, and hyper salivation. This is a significant concern as 89% of veterans diagnosed with PTSD are prescribed serotonin reuptake inhibitors (e.g., antidepressants), and this medication has been shown to be less effective in men (military PTSD is primarily experienced by men; Mohamed & Rosenheck, 2008). However, it is important to note that anti-anxiety medication has been shown to reduce re-experiencing and hyper arousal symptoms associated with PTSD (Outhoff, 2016). With the negative side effects associated with medication, and the fact that medication is less effective in men than women, investigation of alternative treatments is warranted.

Exercise-PTSD Evidence

To address some of the concerns noted above, a few researchers have examined exercise as a viable treatment option for PTSD. Newman and Motta (2007) assessed the effects of aerobic exercise on PTSD, anxiety, and depression in adolescents. Eleven females (age= 15.7yrs) who met full DSM-IV Criteria for PTSD, completed aerobic exercise three times per week for 8 weeks at a moderate intensity. Post-intervention, participants reported a significant reduction in PTSD symptomology (d =1.55), according to the Children's PTSD Inventory (CPTSDI; Saigh, 2004). Additionally, participants reported a significant reduction in depression (d= 6.15) and anxiety (d= 1.11) according to the Children's Depression Inventory (CDI: Kovacs, 1992) and the Revised Children's Manifest Anxiety Scale (RCMAS; Reynolds & Richmond, 1978), respectively. Participants also showed a significant increase in PTSD symptoms (d= 5.53), depression (d= 5.20), and anxiety (d= 3.94) from immediately post-intervention to the 4-week follow-up assessment.

Similar to Newman and Motta, Diaz and Motta (2008) recruited 12 institutionalized females between the ages of 14-17 who reported a score on the Child PTSD Symptom Scale (CPSS; Foa, Johnson, Feeny, & Treadwell, 2001) exceeding 11, the cut-point between low and high traumatic stress. All participants completed 25 minutes of walking three times per week for 5 weeks. Analysis was done on the 11 participants reporting stable scores on the CPSS, 10 of which experienced a significant reduction in PTSD at post-intervention. Follow-up analysis was not included due to poor compliance. Newman and Motta (2007) and Diaz and Motta (2008) highlight the beneficial effects of exercise on PTSD within adolescents. While less relevant to the present study on adults, these two studies both show exercise to be effective in reducing PTSD related symptoms and comorbid conditions associated with PTSD. The following studies address this phenomenon in adults.

Manger and Motta (2005) assessed changes in anxiety, depression, and PTSD severity following 10 weeks of aerobic exercise. Their final sample consisted of 9 participants between the ages of 18-65 (*M* age= 48.1 yrs), all of whom had a score on the Clinician-Administered PTSD Scale for DSM-IV: Current and Lifetime Diagnostic Version (CAPS-DX; Blake et al., 1997) of at least 20, indicating at least mild PTSD symptoms. Additionally, participants were inactive (i.e., self-reported less than 30 min of exercise per week for 1 month prior to study), agreed to abstain from additional exercise or other treatment (e.g., psychotherapy) for the duration of study, obtained physician clearance, were willing to exercise for 10 weeks, and were not suffering from substance abuse (Manger & Motta). Participants were recruited and completed measures of PTSD, depression (Beck Depression Scale-Second Edition; BDI-II; Beck, Steer, & Brown, 1996), and anxiety (State-Trait Anxiety Inventory; STAI-Form Y; Spielberger, 1983) either

5 or 10 weeks prior to the intervention, immediately before the intervention, immediately after the intervention, and at a one-month follow-up. Exercise consisted of a 10 minute warm up (5 min of cycling & 5 min of stretching) followed by 30 minutes of moderate intensity (i.e., 60-80% HR_{max}) treadmill walking/jogging. Heart rate was assessed manually or by use of a Polar Heart Rate Pacer Monitor. Participants were instructed to complete 2-3 exercise sessions per week for 10 weeks. However, inclusion in the final sample was permitted as long as 12 exercise sessions were completed over the 10 weeks.

There was no significant difference between participants assigned to the 5-week or 10-week baseline period, so both were grouped together in all analyses. Results indicated a significant decrease in PTSD severity. Specifically, there was a significant decrease in PTSD severity from beginning baseline (*d*= 1.24) and ending baseline (*d*= 1.01) to post intervention, as well as from beginning baseline (*d*= 1.17) and ending baseline (*d*= 0.92) to one-month follow-up. Whereas 6 participants met full criteria for PTSD (via CAPS-DX) at baseline, only 2 met full criteria post intervention, and at one-month follow-up 4 participants met full criteria for PTSD (Manger & Motta, 2005). Participants also showed a significant reduction in depression according to the BDI-II. Relative to beginning baseline scores, participants showed a reduction in depression at post (*d*= 1.43) and one-month follow-up (*d*= 1.32) assessments. Relative to end of baseline scores (i.e., immediately Pre), participants showed a reduction in depression at post intervention (*d*= 1.08), but only a trend was observed at one-month follow-up (*d*= 0.98) (Manger & Motta). There was a reduction in trait anxiety (via STAI) at post intervention (*d*= 0.96) and one-month follow-up (*d*= 0.88) relative to beginning baseline assessments. However, relative to end baseline, there were no significant differences in trait anxiety post intervention (*d*= 0.71) or after follow-up (*d*= 0.62). There was no change in state anxiety at any time points assessed (Manger & Motta). While the study lacked a control condition and had a small sample size, Manger and Motta provide evidence that exercise has beneficial effects on PTSD and other mental disorders that often co-occur with PTSD.

Fetzner and Asmundson (2014) examined the effects of a “brief” exercise intervention on PTSD symptoms in adults diagnosed with the disorder. Participants were adults (*n*= 25) with primary PTSD [i.e., exceeding 44 on the PTSD checklist-civilian (PCL-C; Weathers, Litz, Herman, Huska, & Keane, 1994) and experiencing at least one item from the re-experiencing and avoidance, three from the negative emotionality, and two from the hyperarousal criteria (National Center for PTSD, 2007)] or subsyndromal PTSD (*n*= 8) [i.e., scoring below 45 on the PCL-C (Blanchard, Jones-Alexander, Buckley, & Forneris, 1996), with endorsement of two criteria total from the major clusters (re-experiencing, avoidance/numbing, hyperarousal; Stein, Walker, Hazen, & Forde, 1997)]. The exercise intervention involved performing six exercise sessions over a 2-week time period. Participants were primarily female (76%; 36.9±11.2, *M±SD* yrs), not currently engaged in psychotherapy, and deemed low risk for physical injury during exercise (i.e., no risk factors on PAR-Q). Using a between-subjects design, Fetzer and Asmundson randomized participants into three conditions, all of which consisted of 20-minutes of aerobic exercise on a cycle ergometer at 60-80% heart rate reserve. Conditions differed only in terms of attentional focus: 1) Cognitive distraction (CD; shift in attention away from somatic sensation); 2) Interoceptive prompts (IP; shift in attention toward somatic sensation); or 3) Exercise only (EO; no shift in attention during exercise). All conditions received exercise and there was no control condition to account for passage of time.

Fetzner and Asmundson showed significant reductions in PTSD symptoms and severity. Specifically, participants reported reduced depression (CES-D; Radloff, 1977), tendency to fear anxiety-related sensations (ASI-3; Taylor et al., 2007), and PTSD severity (PCL-C; Weathers et al., 1994). While no condition or condition by time effects were evident, the main effect of time was significant ($p < .01$) indicating reduced depression throughout the intervention. Effect sizes showed reduced depression for CD ($d = 0.87$), IP ($d = 1.02$), and EO ($d = 0.42$) conditions. Similarly, effects sizes for ASI-3 were large for CD ($d = 2.53$) and EO ($d = 0.96$), but medium for IP ($d = 0.69$). Finally, 88.9 percent of participants reported clinically significant declines in PTSD severity, indicative of a 10-point reduction in PCL-C scores (National Center for PTSD, 2007). Specifically, effect sizes for reduction in total PCL-C scores were large in all conditions: CD ($d = 1.18$); EO ($d = 0.98$); IP ($d = 1.25$). Fetzner and Asmundson also conducted a 1-week and 1-month follow up using the PCL-C. The 1-week follow up indicated 76.2 percent of participants had a reduction in PCL-C scores, but only 14.3 percent were clinically significant reductions. At the 1-month follow up, 86.7 percent of participants showed reduced PCL-C scores, but only 6.7 percent were clinically significant (Fetzner & Asmundson). These findings indicate that PTSD severity, anxiety, and depression can be reduced after only six, 20-min aerobic exercise sessions, independent of attentional focus. Further, it appears that PTSD symptom improvements may not persist once an exercise stimulus is removed.

Rosenbaum et al. (2014) recruited 81 inpatient adults (13 females; 47.8±12.1 yrs) with psychiatrist-confirmed DSM-IV-TR diagnosis of primary PTSD. Participants were randomized into 12 weeks of usual care ($n = 42$), or usual care plus augmentation with resistance/walking exercise treatments ($n = 39$). All participants received, and had equal access to, a combination of psychotherapy, pharmaceutical interventions, and group therapy facilitated by psychologists. Usual care interventions were focused on arousal reduction techniques, including; breathing retraining, relaxation skills, psychoeducation, cognitive therapy, and communication skills (Rosenbaum et al.). Exercise was composed of one weekly supervised resistance exercise session, two home-based sessions, and encouragement to walk 10,000 steps per day, facilitated by use of a pedometer and exercise diary. Resistance exercise sessions consisted of three sets of 10 repetitions of up to six exercises with varying intensity resistance bands. Rest periods between sets were kept between 30-60 seconds. Participants were instructed to use a resistance band that elicited a Rating of Perceived Exertion of 12-17 (i.e., somewhat hard to very hard). Rosenbaum et al. used a progressive resistance exercise intervention, increasing the resistance by 10 percent when participants could perform the first 2 sets of 10 with their current load.

Participants in the usual care plus exercise augmentation group showed a significant improvement in PTSD symptoms relative to the control condition [partial eta^2 (η_p^2)= 0.07). Specifically, the exercise augmentation group showed a decrease of 9.8 on the PCL-C from baseline to follow-up (d= 0.85; Rosenbaum et al., 2014). Large effects were observed between exercise augmentation and usual care only for secondary measures of depression (η_p^2= 0.15) and anxiety η_p^2= 0.17), with moderate effects observed for stress (η_p^2= 0.09). Participants in the usual care plus exercise condition showed a 7.2-point reduction on the DASS depression (d= 0.63) and a 7.1-point reduction on the DASS anxiety scales (d= 0.76). Additionally, the exercise augmentation group showed significantly greater reductions in body fat percentage η_p^2= 0.31), waist circumference (η_p^2= 0.12), and improved PTSD-related sleep quality (η_p^2= 0.08) relative to the usual care only condition. These results are striking as participants in the exercise condition completed a mean of 7 out of 12 supervised exercise sessions (i.e., 58.2%) and data on additional sessions was not analyzed due to poor compliance with exercise diaries (i.e., <20%). With these data, it is difficult to conclude if the resistance exercise sessions or additional walking time were the primary driving force behind these changes. It is not uncommon for individuals living with various psychological disorders to respond more/less favorably to different modes of exercise. Therefore, it is important for future research to tease apart different psychological and physical responses to various modes of exercise within a sample living with PTSD.

A recent study assessed changes in PTSD symptoms following PE or PE plus exercise within patients diagnosed with PTSD (Powers et al., 2015). The exercise consisted of a 30-minute bout of moderate treadmill exercise (i.e., 70% HR_{max}) immediately prior to each PE session. Results indicated that PTSD symptoms significantly decreased pre-to-post in both the PE and PE plus exercise conditions. However, despite both conditions showing improved PTSD symptoms, the between group effect size was very large (d= 2.65), indicating exercise contributes an additional benefit on PTSD symptoms. This is groundbreaking research as combining other gold standard treatment options have not provided additional benefits on PTSD symptoms.

Anxiety

Anxiety is a broad term that covers a wide variety of mental disorders and everyday feelings. It is important to distinguish anxiety disorders from normal anxiety. It is common in everyday life to have feelings of apprehension, worry, tension, nervousness, and even fear.

What separates these everyday feelings of anxiety from an anxiety disorder is severity and duration. Anxiety disorders involve chronic or long term feelings of apprehension, worry, nervousness, and tension. Often these feelings can manifest in situations in which there is little or no reason to have them. Not only do these feelings persist, but they are much stronger in severity, often resulting in altered cognition (e.g., irrational thoughts) and behavior (e.g., avoidance).

Anxiety frequently occurs as a comorbid condition of PTSD. Anxiety is often classified in subcategories of social anxiety disorder (SAD), generalized anxiety disorder (GAD), panic disorder (PD), and agoraphobia (AGO). Spinhoven et al. (2014) reported that comorbidity of PTSD and subcategories of anxiety were: 55.6% for SAD, 42.5% for GAD, 29.4% for PD, and 26.9% for AGO. Further, anxiety has been reported as the most commonly diagnosed mental disorder with an increase in lifetime prevalence from 24.9% in 1994, to 28.8% in 2005 (Kessler et al., 1994; 2005). Given the increased prevalence and diagnosis of anxiety disorders, numerous investigations have explored alternative treatment methods.

Among the most notable contributions to the exercise and anxiety literature was a meta-analysis on the acute and chronic effects of exercise on anxiety (Petruzzello et al., 1991). Specifically, it was found that aerobic exercise significantly reduced generalized anxiety especially in those with elevated levels (Petruzzello et al.). Recently, an updated meta-analysis was performed on only RCTs. Ensari et al. (2014) found a significant reduction in anxiety following an acute bout of exercise. The studies included acute bouts of aerobic and resistance exercise. The above meta-analyses reported moderate reductions in anxiety with overall mean effect sizes of .26 and .16 for the reviews by Petruzzello et al. and Ensari et al., respectively. It is important to note that most participants in these studies were healthy college-aged individuals with normal to low levels of anxiety. As mentioned above, exercise effects on anxiety were greater in individuals with elevated baseline levels.

To further demonstrate this, Motl and Dishman (2004) used caffeine pills to increase anxiety symptoms prior to exercise. Participants received caffeine or placebo and then completed an acute bout of exercise or quiet rest. Anxiety was significantly reduced in participants who received caffeine and exercise only (Motl & Dishman; *d*= 0.34). Similarly, Petruzzello, Snook, Gliottoni, and Motl (2009) had individuals with high and low trait anxiety cycle for 20 minutes at a moderate intensity. The high trait anxious group showed significant reductions in state anxiety, with effect sizes of 1.0, 1.0, and 1.17 at 5, 20, and 60 min post exercise respectively (Petruzzello et al.). The low trait anxious group only showed a small improvement (*d*= 0.29) 60 minutes after exercise. Taken together, exercise appears to have a small to moderate effect on anxiety reduction. However, when individuals have increased anxiety, exercise appears to have a much larger effect. This is of specific interest as individuals with mental health disorders often experience increased anxiety (Keane, 2014).

Anxiety disorders have typically been treated with medication and psychotherapy. While both methods have been successful in reducing anxiety symptoms, medication and psychotherapy exert a heavy burden on health care costs. Greenberg et al. (1999) assessed and estimated the economic burden associated with anxiety disorders in the United States to be 42.3 billion dollars. Further, anti-anxiety medications can have a wide range of negative side effects and only provide temporary symptom relief (i.e., symptoms return once medication ceases). Common side effects from anti-anxiety medication (e.g., benzodiazepines) include, but are not limited to, slowed reaction times, memory impairment, drowsiness, muscle weakness, vertigo, confusion, irritability, depression, addition, and significant risk of drug interactions (Longo & Johnson, 2000)

Exercise has the potential to treat anxiety disorders in those also living with PTSD without the additional side effects of more medication. In addition, exercise is an affordable alternative to medication and may help reduce the economic burden of mental disorders. It is vital to explore how exercise can be used to treat individuals living with different comorbid disorders, specifically PTSD.

Depression

Individuals who live with PTSD are at a significant risk for developing other psychiatric disorders. A recent review has estimated 75 percent of individuals diagnosed with PTSD suffer from at least one additional mental health disorder (Katzman et al., 2014). One common comorbid disorder is depression. Ameringen, Mancini, Patterson, and Boyle (2008) assessed lifetime PTSD and comorbid disorders, with results indicating that 74 percent of patients living with PTSD also suffer from major depressive disorder (MDD). A similar study reported 84.4 percent of patients living with PTSD also suffer from MDD, and 41.9 percent of patients living with PTSD suffer from dysthymia (Spinhoven et al., 2014). Further, individuals with PTSD have a 2.4 times greater risk for developing MDD relative to those without PTSD (Ameringen et al.). While the primary purpose of the proposed study is to determine if an acute bout of exercise is feasible within a population living with subsyndromal PTSD, an equally vital goal is to demonstrate the potential to improve other mental and physical health concerns within this population.

Numerous reviews and meta-analyses have been conducted to examine the effects of exercise on depression. Lawlor and Hopker (2001) reviewed 14 studies on exercise and depression and concluded exercise reduces depression to a greater extent than no treatment conditions. Cooney et al. (2014) conducted a meta-analysis from 39 individual studies, concluding that exercise significantly reduces depression compared with no treatment, placebo, or active controls (e.g., relaxation, meditation). Other meta-analyses have included resistance and aerobic exercise effects on depression. Silveira, Moraesa, Oliveira, Coutinho, and Andrea (2014) examined the effectiveness of both resistance and aerobic exercise on depression, with results indicating no significant differences between mode (i.e., resistance or aerobic) or intensity of exercise. As such, Silveira et al. combined all data to reveal a 0.61 standard deviation reduction in depression with exercise interventions. Further, Stanton, Reaburn, and Happell (2013) conducted a review on the effectiveness of resistance exercise, cardiovascular exercise, and a combination of both in reducing depression. Male and female participants of all ages and varying depression severity showed significantly reduced depression after cardiovascular exercise only, resistance exercise only, or a combination of both, with no difference among modes (Stanton et al.).

One common and widely accepted treatment for depression is medication. However, there are significant side effects to taking antidepressants. When depression is occurring with other psychiatric disorders (e.g., PTSD), stacking multiple medications could potentially increase negative effects of pharmacological treatment. Not only has exercise has been shown to significantly reduce MDD, but this effect is comparable to both medication and psychological therapy. Blumenthal et al. (2007) compared home-based and supervised group exercise with both placebo and medication in the treatment of MDD. Results indicated a significant reduction over the 16 week randomized placebo-controlled study across all conditions. Specifically, after controlling for early responders, Blumenthal et al. showed all active treatment groups had higher remission rates relative to the placebo, with no difference observed between exercise and medication or between exercise groups. These findings have been supported in recent reviews. Knapen et al. (2015) reviewed four meta-analyses on exercise and depression, concluding that exercise is highly effective for treating depression. Specifically, physical exercise was shown to be more effective than no treatment controls and as effective as antidepressant medication and psychotherapy, but only for mild to moderate depression. Knapen et al. concluded that for severe depression exercise is a beneficial complement to traditional treatments, but not as effective alone. Further, exercise improved participants' physical health, body image, stress management, quality of life, and independence. Individuals with PTSD are at an increased risk for complications related to all of these factors. These improvements are as vital as reductions in depression as not only are individuals with PTSD at an increased risk for inactivity, cardiovascular disease, and metabolic syndrome, but individuals with depression are also at an increased risk for the same conditions. 30.5 percent of individuals with MDD also suffer from metabolic syndrome, making their relative risk 1.5 times higher than individuals without MDD (Vancampfort et al., 2013).

Obesity and Metabolic Syndrome Among Individuals with PTSD

The prevalence of obesity in the general population has received significant attention in recent literature, but often overlooked is the overwhelming association between PTSD and obesity/metabolic syndrome. In a cross-sectional study, patients with various mental disorders were evaluated for metabolic profiles. Results indicated that 72 percent of PTSD patients were diagnosed with metabolic syndrome; this was larger than any other mental disorder (Jin et al., 2009). Further, past year PTSD was associated with a 1.51 odds ratio of obesity (i.e., 1.51 times more likely to be obese than if no PTSD; Pagoto et al., 2012). Applied to the national statistic of one-third of Americans being obese (Flegal, Carroll, Ogden, & Curtin, 2010), PTSD odds ratio indicated over 50 percent of individuals living with PTSD are obese. Additionally, Spitzer et al. (2009) found that PTSD was significantly associated with increased incidence of cardiovascular and pulmonary disease. Increases in heart disease and decreases in physical activity levels have also been significantly associated with PTSD (Buckley, Mozley, Bedard, Dewulf, & Greif, 2004). With the increased prevalence rates of obesity, metabolic syndrome, and heart complications among individuals living with PTSD, recent reports have highlighted the need to identify treatment options that affect all of these health-related sequelae of PTSD (i.e., physical and psychological). Rosenbaum, Tiedemann, Berle, Ward, and Steel (2015) discuss the importance and potential effectiveness of using exercise to treat cardiometabolic dysfunction associated with PTSD. These recommendations are grounded in literature supporting exercise interventions to combat obesity and cardiovascular events, specifically in those living with mental illness.

Physical activity and exercise have been used to combat obesity and cardiovascular disease for decades. The American College of Sports Medicine recommends a minimum of 150 minutes per week of moderate intensity physical activity for health improvements, and 200-300 minutes per week for long-term weight loss (Donnally et al., 2009). These recommendations have been supported by numerous systematic reviews and meta-analyses that indicate physical activity (e.g., aerobic, anaerobic, and/or resistance) significantly decreases fat mass, improves cardiac functioning, decreases risk of metabolic syndrome, and improves body composition in all ages (García-Hermoso, Sánchez-López, & Martínez-Vizcaíno, 2015; Ismail, Keating, Baker, & Johnson, 2012; Strasser & Schobersberger, 2011). Further, Braith and Stewart (2006) conducted a large scale review to highlight the benefits of resistance and aerobic exercise. Results indicated that aerobic exercise increases bone mineral density, insulin sensitivity, high-density lipoprotein, basal metabolism, and largely increases physical endurance, while decreasing fat mass, low-density lipoprotein, basal insulin levels, insulin response to glucose challenge, resting heart rate, systolic and diastolic blood pressure. Further, resistance exercise increases muscle mass, insulin sensitivity, high-density lipoprotein, basal metabolism, physical endurance, and largely increases bone mineral density and strength; as well as decreasing fat mass, low-density lipoprotein, basal insulin levels, insulin response to glucose challenge, systolic and diastolic blood pressure (Braith & Stewart). As mentioned above, even without direct effects on PTSD symptomology, understanding the psychological responses to an acute bout of exercise within a population living with subsyndromal PTSD will provide the knowledge to develop an exercise intervention aimed at improving cardiovascular health and decreasing obesity in this special population.

Health-Related Quality of Life

Beyond decreased cardiovascular health and increased obesity, individuals living with PTSD often experience a further reduction in quality of life. Pacella et al. (2013) conducted a recent meta-analysis examining 62 studies on PTSD and contributing physical health concerns. Results indicated that individuals with higher PTSD symptoms have elevated levels of pain, general medical conditions, and reduced physical health. Veterans diagnosed with PTSD often experience increased risk of stroke, greater rates of smoking, and lower physical activity rates as compared to age-matched controls (Buckley et al., 2004). Hoge et al. (2007) analyzed somatic symptoms and health in 2,815 Iraq war veterans with and without PTSD. It was found that 16.6 percent of soldiers met criteria for PTSD 1 year after returning from Iraq. Of those 468 soldiers, 71.1 percent reported trouble falling or staying asleep, 74.9 percent reported feeling tired or having little energy, 46.7 percent self-rated their health as poor or fair, 23.6 percent reported pounding or racing heart rates, 37.6 percent reported two or more sick call visits in the previous month, and over half reported pain in various locations (Hoge et al.). Further, veterans with PTSD had significantly higher rates of all health-related quality of life measures listed above (except menstrual cramps) relative to veterans without a PTSD diagnosis (Hoge et al.).

Individuals with PTSD suffer from a host of comorbid disorders and general health concerns. While there is no cure to all the former concerns, exercise has been shown to significantly help across most symptoms. Puetz, Flowers, and O'Connor (2008) showed a trend for decreased fatigue after a 6-week low intensity exercise intervention, and increase in vigor following low and moderate intensity exercise interventions. Reductions in fatigue have also been shown in populations with preexisting conditions. Females (*N*= 25) with confirmed multiple sclerosis showed a significant decrease in fatigue after 20 minutes of cycling at 60 percent of their VO_{2peak} (Petruzzello & Motl, 2011). Gine-Garriga et al. (2013) found that inactive patients randomly assigned to a 3-month Primary Health Care physical activity program reported significantly fewer healthcare visits than those assigned to a control group, over the subsequent 12 months. Hoge et al. (2007) reported that 40.2 percent of veterans diagnosed with PTSD also suffer from back pain. A recent pilot study suggests progressive exercise training could reduce pain sensitivity in patients with PTSD by increasing the capacity for exercise-induced release of allopregnanolone, pregnanolone, and neuropeptide Y (Scioli-Salter et al., 2016). Further, physical activity has been shown to both prevent lower back pain, and relieve chronic low back pain (Vuori, 2001). In a recent meta-analysis, it was concluded that regular exercise improves total sleep time, sleep efficiency, sleep onset latency, and sleep quality (Kredlow, Capozzoli, Hearon, Calkins, & Otto, 2015). Roberts, Maddison, Simpson, Bullen, and Prapavessis (2012) reviewed 15 studies assessing exercise effects on smoking. Results indicate that exercise of various intensities and modes has a positive impact on cigarette cravings and tobacco withdrawal symptoms, decreasing both. Similarly, exercise has been shown to have beneficial effects on alcohol use disorders (Giesen, Deimel, & Bloch, 2015). Exercise has even been shown to improve physical health perceptions in patients who suffered a mild, non-disabling stroke (Faulkner et al. 2015). Additionally, exercise has been shown to increase antioxidant indicators and decrease pro-oxidant indicators, suggesting physical activity improves health-related outcomes (Sousa et al., 2017). There is ample evidence that exercise is beneficial for many different health concerns, and that exercise could greatly benefit individuals with PTSD.

Exercise Conclusion

While the evidence presented above is by no means a full review, nor does it capture the extent to which exercise has been used within the health sector, it does shed light on the possibilities of exercise being used to combat a multitude of symptoms of, and improve the quality of life in, individuals living with PTSD. PTSD is not a singular condition, but one that impacts an individual's overall health. While psychotherapy and pharmacological treatments may benefit specific symptoms, these traditional methods cannot alleviate all the comorbid disorders associated with PTSD. While exercise is not the gold standard treatment for anxiety, depression, fatigue, pain, sleep disorders, substance abuse, obesity, cardiovascular disorders, or overall physical/mental health, research has consistently shown that exercise exerts significant benefits on all those conditions. All of these small to medium scale benefits could stack to have a large, beneficial impact on individuals with PTSD and significantly improve their quality of life, as well as the quality of life of their loved ones. However, as with any special population, it is imperative to determine how individuals will respond to an exercise program before implementing a large scale intervention. The present study aims to address this question by assessing various perceptual and psychological responses to an acute bout of high intensity interval exercise (HIIE) and moderate intensity continuous aerobic exercise (MIA). In doing so, the aim is to not only show exercise is a safe and viable option for individuals living with PTSD, but that exercise can reduce some symptoms of PTSD after a single bout.

Contribution of the Current Study

While limited research has been conducted on exercise and PTSD, results are promising. Significant reductions in PTSD symptoms have been shown for both females and males, across a wide range of ages (i.e., 14-65 years), and from interventions lasting from 2-12 weeks. However, research has yet to examine the effects of a single exercise session on anxiety, depression, or PTSD-related symptoms in a population with PTSD. Although early detection and treatment for PTSD has been increasing, there continues to be a need for immediate, short-term and cost-effective relief of direct and indirect symptoms. Addressing this void would answer the question of whether reduction in symptoms can be more immediate or whether such reduction only occurs following the accumulation of multiple treatment sessions over several weeks.

Also, current PTSD and exercise research does not address affective and exercise enjoyment responses. This is surprising as dropout/non-adherence has been linked to affective responses (Ekkekakis, Hall, & Petruzzello, 2008; Williams et al., 2008; Williams, Dunsiger, Jennings, & Marcus, 2012) and enjoyment levels (Dishman, Sallis, & Orenstein, 1985). While data on adherence rates for exercise interventions to treat PTSD are limited, one study addressed this concern. Rosenbaum et al. (2014) randomized 39 participants into a 12-week exercise study. Results indicated adherence rates to one supervised resistance exercise session per week for 12 weeks was only 58 percent. Additionally, less than 20 percent of participants completed and returned exercise logs on the remaining 2 exercise sessions per week (Rosenbaum et al.). This is not surprising as dropout from empirically supported PTSD treatments (e.g., psychotherapy) are as high as 30 percent (Hembree et al., 2003). Watts et al. (2014) conducted the largest compliance study to date, within veterans diagnosed with PTSD. Of the 1,924 newly diagnosed patients that were seen by a Veterans Affairs (VA) specialist, only 6% received evidence-based psychotherapy (i.e., PE or CBT). Further, of the limited number that received treatment, the median number of therapeutic visits was 5 (Watts et al.). As the recommended number of sessions for CBT is 12 and 8-18 for PE, most veterans receiving treatment did not comply to the full course of therapy. According to Watts et al., only 2% of veterans newly diagnosed with PTSD received the minimal empirically supported 8 sessions to indicate improvement in PTSD symptoms. Therefore, it should be of primary interest to maximize exercise adherence rates in individuals with PTSD, especially due to loss of exercise-induced reductions in PTSD symptom severity and comorbid conditions following discontinuation of exercise. Despite 89 percent of participants showing clinically significant reductions in PTSD severity following two weeks of exercise, only 14.3 percent and 6.7 percent of participants had clinically significant reductions at one-week and one-month follow-ups, respectively (Fetzner & Asmundson, 2014). Additionally, Newman and Motta (2007) showed significant reductions in PTSD symptom severity, depression, and anxiety following 8-weeks of aerobic exercise in adolescent females. However, one-month follow-up analysis revealed significant increases, albeit not back to baseline, in PTSD symptom severity, depression, and anxiety relative to post-intervention (Newman & Motta). Given the limited evidence, it appears that continued exercise participation is required to maintain the reduction in PTSD symptoms following exercise interventions. As such, it should be a primary concern to develop programs aimed at maximizing affective responses and enjoyment levels.

The exercise conditions in the present study consist of a traditional moderate intensity aerobic exercise (MIA) and a high intensity interval exercise (HIIE) protocol. To the best of our knowledge this is the first exercise and PTSD study to include multiple modes of exercise. Addressing the question of enjoyability of exercise modes, affective responses to those modes, and whether there are any beneficial effects on PTSD, anxiety, and depression symptoms is of utmost importance. Specifically, as PTSD symptom severity has been show to increase at 1-month post assessments (following exercise invoked reductions; Newman & Motta 2007; Fetzner & Asmundson, 2014), it is imperative to maximize exercise enjoyment and affect. As the proposed population (i.e., individuals with PTSD) exhibits decreased activity levels, it is imperative to further elucidate the exercise intensity-affect-enjoyment link with the ultimate goal of influencing exercise adherence.

The purpose of the present study is to examine, in a sample of individuals with PTSD-related symptoms: (a) the feasibility of implementing an acute bout of MIA and HIIE; (b) whether an acute bout of exercise reduces anxiety, depression, and improves affective valence in individuals with PTSD-related symptoms more than a no-exercise control condition; and (c) how an acute bout of HIIE compares with more "traditional" MIA in such psychological changes. The overall aim of the project is to show that exercise is a safe, viable option for individuals living with PTSD-related symptoms, determine the mode of exercise that produces the most favorable affective and enjoyment responses, and determine whether an acute (i.e., single) bout of exercise can reduce symptoms of co-morbid psychological disorders (e.g., anxiety & depression) in individuals with PTSD-related symptoms.

The current study seeks to further explore alternative treatments/management options for individuals living with PTSD. First, it is hypothesized that both HIIE and MIA will significantly reduce anxiety and depression, as well as improve affective responses relative to a no exercise control. Additionally, based on previous research assessing enjoyment and affective responses to HIIE and moderate aerobic exercise, it is hypothesized that the HIIE condition will result in similar enjoyment relative to MIA. However, due to the vigorous intensity of HIIE and that affective responses to exercise are intensity dependent (Kilpatrick, Kraemer, Bartholomew, Acevedo, & Jarreau, 2007), it is hypothesized that affective valence during exercise will be more pleasant/less unpleasant during the MIA relative to the HIIE condition. Further, due to the high-intensity nature of HIIE, affective valence during HIIE is expected to be significantly less positive relative to SED. Additionally, it is hypothesized that participants will report significant increases in positive affect (as reflected by increases in pleasant-activated affective states like energy and/or pleasant-deactivated affective states like calmness) and decreases in negative affect (as reflected by decreases in unpleasant-activated affective states like tension and/or unpleasant-deactivated affective states like tiredness) after completion of the MIA and HIIE conditions relative to the SED condition. This innovative approach to improve psychological symptoms of PTSD and comorbid mental disorders acutely, will advance scientific understanding on the psychological effects of exercise within a special population. The impact of a successful project will be to provide upwards of 17.1 percent of veterans and 6.8% of civilians who live with PTSD a safe, cost effective daily mood enhancing alternative (Hoge et al., 2006; Seal et al., 2007). A successful project will result in a better understanding of exercise effects on PTSD symptoms, depression, and anxiety within a special population. Further, this study will provide preliminary data to explore a longitudinal exercise study aimed at maximizing adherence (i.e., improved affect/enjoyment) and symptom reduction in individuals living with PTSD.

CHAPTER 3

RESEARCH METHODS

Participants

Participants were residents of the Champaign-Urbana area (*N*= 25: 9 males, 16 females; see Table 2 for descriptive statistics) recruited from flyers placed on campus bulletin boards, through the Center for Wounded Veterans in Higher Education (CWVHE) and the Division of Disability Resources and Educational Services (DRES) at the University of Illinois Urbana-Champaign. All participants met the minimum requirements indicating subsyndromal PTSD [i.e., having at least one symptom in each of the major DSM-5 clusters (intrusion/re-experiencing, avoidance/numbing, negative alterations in cognitions/mood, negative arousal/hyperactivity; refer to Table 1), but not necessarily qualifying for a full diagnosis: Breslau, Lucia, & Davis, 2004; Pietrzak, Goldstein, Southwick, & Grant, 2011; Stein, Walker, Hazen, & Forde, 1997][1]. Scores on the PCL-5 can range from 0 to 80, with the range in the present study being 16 to 73. The average PCL-5 score in the present study was 47.64, with an accepted cut-point for probable PTSD set at 33 on the PCL-5 (Weathers et al., 2014). In the present study, 19 of the 25 participants reported a PCL-5 score greater than 33. Additionally, 10 participants (7 females) reported exercising vigorously on a regular basis, 8 (6 females) reported frequently lifting moderately heavy objects, 18 (12 females) reported frequently climbing stairs, and 19 (15 females) reported regularly engaging in informal physical activity. All participants were instructed to refrain from drinking alcohol at least 1 day prior to testing and to refrain from exercise 48 hours prior to testing. Additionally, there was at least 48 hours between acute

[1] It is important to note that one participant did not meet the minimum requirements indicating subsyndromal PTSD, but was previously diagnosed with PTSD and was included in all analyses.

exercise conditions. All participants were offered monetary compensation for volunteering their time, in the amount of 10 dollars per completed session or 50 dollars if all four sessions were completed.

Table 2
Descriptive Information for the Sample Participants

Variable	All (*N* = 25)		Females (*n* = 16)		Males (*n* = 9)		Sex Differences		
	M	*SD*	*M*	*SD*	*M*	*SD*	M_{diff}	*SE*	*p*
Age (yrs)	25.6	9.1	26.6	10.1	23.8	7.3	2.9	3.8	.466
Height (cm)	167.9	7.5	163.8	5.6	175.3	4.0	11.4	2.1	<.001
Body mass (kg)	69.3	15.6	67.3	18.2	72.7	9.6	5.4	6.6	.419
BMI ($kg·m^{-2}$)	24.5	5.1	24.9	6.0	23.7	3.2	1.2	2.2	.576
Est.Vo_{2peak} ($ml·kg^{-1}·min^{-1}$)	34.5	10.0	29.0	6.9	44.2	6.5	15.2	2.8	<.001
PCL-5 score	47.6	16.1	52.7	13.3	38.7	17.3	14.0	6.2	.033
BDI-II score	21.5	11.0	26.0	10.0	13.6	8.0	12.4	3.9	.004
TAI score	51.1	13.4	56.1	13.0	42.2	9.2	13.9	4.9	.010
Drinks·wk^{-1}	5.1	9.3	4.2	5.1	6.7	14.3	2.6	3.9	.516
Cigarettes·day^{-1}	0.2	.5	0.2	.5	.2	.1	.0	.2	.926
Ex Frequency (days·wk^{-1})	2.9	1.5	2.7	1.5	3.3	1.5	.6	.6	.351

Procedure

Participants were recruited through email solicitations via the CWVHE, campus announcements, as well as flyers at participating venues on campus. Interested participants emailed the Exercise Psychophysiology Laboratory (ExPPL) and set up a screening session. This screening consisted of the *PTSD Check-List for DSM-5* (PCL-5; Weathers et al., 2013) to assess PTSD symptoms (in DSM-5 clusters of re-experiencing, avoidance, negative emotionality, hyperarousal) for determination of inclusion (i.e., having at least one symptom in each of the major DSM-5 clusters). Upon meeting inclusion criteria, participants were scheduled for their first of four sessions. All sessions were held either at the CWVHE or the Exercise

PsychoPhysiology Laboratory (ExPPL) in Freer Hall. Each of the 4 test sessions were scheduled with a minimum of 2-3 days between sessions to ensure adequate recovery of cardiovascular and musculoskeletal systems.

During the first visit, participants completed the Physical Activity Readiness Questionnaire (PAR-Q; Thomas, Reading, & Shephard, 1992) and a health and physical activity history inventory to insure no contraindications existed for physical activity (e.g., cardiovascular problems). If participants indicated any contraindications to physical activity, follow-up questions were asked to ascertain the extent of symptoms to determine if participation in the exercise study was safe. Additionally, participants read and signed an IRB approved informed consent document and then completed a series of questionnaires to assess various individual differences and traumatic life events. These included the *Life Events Checklist* (Blake et al., 1995; see Table 3), the *Trait Anxiety Inventory* (TAI; Spielberger, 1983), and the *Beck Depression Inventory-II* (BDI-II; Beck et al., 1996). Both the TAI and BDI-II were used as baseline measures only (see Table 2 for values). After completion of all initial questionnaires, participants performed an exercise test to determine estimated aerobic capacity (est. VO_{2peak}).

The estimated VO_{2peak} test was well tolerated by all participants, with no symptom-limited tests observed. VO_2 ($L \cdot min^{-1}$) and VCO_2 ($L \cdot min^{-1}$) were graphically represented to determine estimated Ventilatory Threshold (VT) for each participant. The VT was determined as the point in which VO_2 and VCO_2 intercepted. This allowed the determination of individualized exercise intensity in the subsequent conditions (i.e., special attention was given to HR values to make sure participant did not exceed HR at VT). Average estimated VO_{2peak} in the present sample was 34.48 ± 9.97 $ml \cdot kg^{-1} \cdot min^{-1}$ (females: 29.02 ± 6.93 $ml \cdot kg^{-1} \cdot min^{-1}$; males: 44.18 ± 6.54

$ml \cdot kg^{-1} \cdot min^{-1}$). A modified Bruce protocol was performed, using a Quinton motorized treadmill (Bruce et al., 1949). This protocol consisted of 3-minute stages starting at a 10 percent incline and speed of 1.7 miles per hour ($mi \cdot hr^{-1}$). Every 3 minutes, incline was increased by 2 percent up to a maximum of 15 percent, and speed was increased to 2.5, 3.4, 4.2, 5.0, and 5.5 $mi \cdot hr^{-1}$ respective to each stage increase. Estimated VO_{2peak} was measured using a computerized indirect calorimetry system (ParvoMedics TrueOne 2400), with measurements taken every 20 seconds for respiratory exchange ratio (RER), oxygen uptake (VO_2), and heart rate (HR). The graded exercise test involved successive 3-minute bouts of treadmill walking/jogging until the participant's heart rate reached ~85% of their age-predicted maximal heart rate (HR; calculated as 208 – 0.7 x age), an RER ≥ 1.1, or the participant reached volitional exhaustion. As this was a submaximal test, no participant reached volitional exhaustion and the experimenter stopped the test when the appropriate levels of HR or RER were reached. After completion of the exercise test, participants were monitored until HR returned to normative values, at which point they were scheduled for the subsequent 3 sessions and then permitted to leave.

Table 3
Specific Symptoms and Prevalence for Each Given Criteria of DSM-5 Diagnosis of PTSD

Criterion	Symptoms	Prevalence
A1	Directly experiencing the traumatic event	96%
A2	Witnessing, in person, the event as it occurred to others	88%
A3	Learning that the traumatic event occurred to a close family member or friend	92%
A4	Not Sure	56%
B1	Recurrent, involuntary, and intrusive distressing memories of the traumatic event	80%
B2	Recurrent distressing dreams in which the content and/or effect of the dream are related to the traumatic event	64%
B3	Dissociative reactions in which the individual feels or acts as if the traumatic event was recurring	64%
B4	Intense or prolonged psychological distress at exposure to internal or external cues that symbolize or resemble an aspect of the traumatic event	92%
B5	Marked psychological reactions to internal or external cues that symbolize or resemble an aspect of the traumatic event	72%
C1	Avoidance of or efforts to avoid distressing memories, thoughts, or feelings about or closely associated with the traumatic event	76%
C2	Avoidance of or efforts to avoid external reminders that arouse distressing memories, thoughts, or feelings about or closely associated with the traumatic event	84%
D1	Inability to remember an important aspect of the traumatic event	60%
D2	Persistent and exaggerated negative beliefs or expectations about oneself, others, or the world	84%
D3	Persistent, distorted cognitions about the cause or consequences of the traumatic event that lead the individual to blame himself/herself or others.	56%
D4	Persistent negative emotion state	88%
D5	Markedly diminished interest or participation in significant activities	68%
D6	Feelings of detachment or estrangement from others	76%
D7	Persistent inability to experience positive emotions	68%
E1	Irritable behavior and angry outbursts typically expressed as verbal or physical aggression toward people or objects	68%
E2	Reckless or self-destructive behavior	56%
E3	Hypervigilance	80%
E4	Exaggerated startle response	76%
E5	Problems with concentration	84%
E6	Sleep disturbance	84%

Table 4
Randomized, Counter-balanced, Within-subjects Design

Order	# Completed	Order	# Completed
HIIE/MIA/SED	4	MIA/SED/HIIE	4
HIIE/SED/MIA	4	SED/HIIE/MIA	4
MIA/HIIE/SED	5	SED/MIA/HIIE	4

Over the course of the next few weeks, participants completed 3 randomly ordered, counterbalanced conditions: moderate intensity aerobic exercise (MIA), high-intensity interval exercise (HIIE), and a no exercise control (SED; see Table 4). For the MIA condition, participants exercised for 35 minutes on a treadmill. This consisted of a 5 min warm up and a 5 min cool down (at 40% est. VO_{2peak}; corresponding to light intensity [Garber et al., 2011]), with 25 minutes of running/jogging at a moderate intensity (i.e., 60% individuals VO_{2peak}; Garber et al.). Special care was taken to insure the intensity remained below the individual's VT determined from the est. VO_{2peak} test on day 1. Intensity was monitored throughout the session using HR and ratings of perceived exertion (RPE; assessed every 5 min); treadmill speed was increased/decreased accordingly to maintain HR at a moderate intensity (i.e., approximately 60-70% est. VO_{2peak} [derived from Swain, Abernathy, Smith, Lee, & Bunn, 1994] & RPE of 12-15; "somewhat hard" to "hard"). Average exercise intensity during HIIE was 80.36% est. VO_{2peak} and 71.96% est. VO_{2peak} for MIA. For the SED condition, participants completed the same testing protocols while remaining sedentary. The laboratory environment was identical to the "active" conditions, and participants interacted with the researchers in the same manner. Specifically, participants remained sitting in a comfortable chair, were permitted to read magazines provided by the laboratory, were asked not to use cellular devices (specifically social media), and engaged in light conversation with the lab staff in a manner and tone consistent with both active conditions.

The HIIE condition consisted of a 5 min warm up and a 5 min cool down (i.e., 5 min at est. 40% VO_{2peak} on treadmill) with 25 minutes of HIIE exercise. Participants performed high-intensity interval exercises in intervals of 3 minutes with 2-minutes rest between each set. Specifically, participants completed 5, 3 min bouts of actual exercise (i.e., 15 min) and 5, 2 min rest periods (i.e., 10 min). Exercises consisted of aerobic movements (e.g., butt kicks, high knees, & jump rope) and resistance movements (e.g., push-ups, squats, shoulder press; See Table 5a); participants were encouraged to give “all out” effort during the HIIE condition. The exercise blocks were designed to provide a full body workout (i.e., targeting all major muscle groups & the cardiovascular system) in a time efficient protocol. The resistance movements involved combinations of body weight (BW) and body bar (BB) exercises. Proper instructions were provided prior to the initiation of each set of exercises. Each exercise block consisted of 3 exercises performed twice for 30 seconds each time (e.g., Block 1: 30 sec push-ups, 30 sec triceps extensions, 30 sec shoulder press, 30 sec push-ups, 30 sec triceps extensions, 30 sec shoulder press). Targeting multiple muscle groups with minimal rest is ideal to maximize training efficiency without overloading individual muscles. Due to the difficulty of some of the exercises, modifications were provided if the participant was having difficulty or if requested (see Table 5b). In the present study, 2 participants (2 females) requested modifications. The first participant completed standing climbers instead of traditional mountain climbers, and completed alternating lunges in place of burpees. The second participant completed squats in place of bent over rows, and alternating lunges instead of burpees. All other participants completed the original protocol highlighted in Table 5a. As the goal of HIIE was to target specific muscle groups while keeping the participants HR elevated, the specific exercise was less important than continuous activity.

Table 5a

Full High-Intensity Interval Exercise (HIIE) Protocol

Exercises	Block 1	Block 2	Block 3	Block 4	Block 5
	resistance	cardio	resistance	cardio	resistance
Ex 1 & 4	Push-ups (bw)	Mountain Climbers (bw)	Bent Over Rows (bb)	Burpees (bw)	Squats (bb)
Ex 2 & 5	Triceps Extension (bb)	Jump Rope (bw)	Biceps Curl (bb)	Calf Jumps (bw)	Upright Row (bb)
Ex 3 & 6	Shoulder Press (bb)	Butt Kicks (bw)	Army Rowers (bw)	High Knees (bw)	Elbow Plank (bw)

bb = body bars; bw = body weight.

Table 5b

Alternative Exercises for HIIE

Exercise	Modification 1	Modification 2
Push-ups (bw)	Modified (knee)	Wall Push-ups
Mountain Climbers (bw)	Standing climbers	Standing knee crunch
Jump Rope (bw)	Box step ups	Lateral leg raise
Butt Kicks (bw)	Alt back kicks	N.A.
Army Rowers (bw)	Bicycles	Flutter kicks
Burpees (bw)	Broken Burpees	Alt lunges
Calf Jumps (bw)	Calf Raises	N.A.
High Knees (bw)	Standing Knee Raises	N.A.
Elbow Plank (bw)	Hand Plank	Elbow Plank on knees
Squats (bb)	Squats no bb	Wall sit
*Other bb exercises	Lower bb weight	Perform exercise w/o bb

bb = body bars; bw = body weight

*include: Triceps extension, shoulder press, biceps curls, bent rows, upright rows

All conditions were randomized and counterbalanced; participants were informed that they would complete three conditions, but that they could receive any combination of conditions (i.e., HIIE, MIA, SED). Further, participants were not aware of what condition they were performing until all baseline (i.e., Pre) affective measures were collected. Participants were then fitted with a heart rate monitor and instructed on which condition was being performed. All conditions were 35 minutes in duration and participants remained in the laboratory for an additional 40 minutes after completing each condition. The additional 40-minute period was used to monitor post exercise affective valence, as well as to monitor each participants physiological state (i.e., HR) to ensure proper recovery. The total duration of each exercise session was approximately 80-90 minutes: 5-min Pre questionnaires, 35-min per condition, 40-min recovery period, 5-min post questionnaires. Participants completed various questionnaires before (Pre), every 5-minutes during, immediately after (Post0), as well as 20 (Post20) and 40 (Post40) min post each condition (see Table 6). Additionally, during HIIE, FS and RPE were assessed at the end of each exercise interval (i.e., min 3) and at the end of each rest period (i.e., min 5) for each 5-min block. During all exercise sessions, participants were allowed to drink water ad libitum, but no music was permitted. For safety, there was a minimum of two ExPPL staff members present and ready to assist participants during every session. Additionally, there was a certified clinical psychologist on-site at the CWVHE in case an adverse event occurred during any component of the research study. There were no adverse events in the present study.

Table 6
Time of Completion for Individual Questionnaires

Measure	Pre	During (every 5 min)	Post0	Post20	Post40
AD-ACL	X		X	X	X
SAI	X		X	X	X
Depression	X		X	X	X
PACES			X		
FS	X	X	X	X	X
RPE	X	X	X	X	X
Heart Rate		X			

AD-ACL = Activation Deactivation Check-List; SAI = State Anxiety Inventory; PACES = Physical Activity Enjoyment Scale; FS = Feeling Scale; RPE = Rating of Perceived Exertion

Measures

Various measures were collected from the participants, some of which assessed individual differences and some of which assessed more immediate responses to treatment conditions.

Physical Activity Readiness Questionnaire (PAR-Q). The PAR-Q (Thomas et al., 1992) is a 7-item questionnaire designed to assess an individual's ability to participate in physical activity. Participants were asked to check "yes" or "no" to 7 statements assessing various aspects of health (e.g., "Do you feel pain in your chest when you do physical activity?", "Do you lose your balance because of dizziness or do you ever lose consciousness?"). The PAR-Q is used as a baseline screening assessment. In the event a participant answered "yes" to any items, follow up questions were used to assess the severity of symptoms to determine if inclusion in the study was safe.

PTSD CheckList for DSM-5 (PCL-5). The PCL (Weathers et al., 2014) is a 20-item self-report measure for assessing PTSD symptom severity. In some cases, it can be used to determine whether a person meets criteria for PTSD. It is a less valid measure of diagnosis and more appropriate for assessing PTSD symptom severity. Participants respond to 20 different problems that represent stressful experiences by choosing the response that best fits how much they have been bothered by that problem in the past month, using a 5-point Likert scale ranging from 0 “Not at all” to 4 “Extremely”. Scores on the PCL-5 range from 0-80, with higher scores indicating greater PTSD symptom severity. Scores of 33 or higher have been suggested as a potential cut off for probable diagnosis, although lower cut off scores are often used during initial screenings (Weathers et al.). The PCL-5 has demonstrated strong internal consistency (α = .94) and test-retest reliability (r = .82; Blevins, Weathers, Davis, Witte, & Domino, 2015).

Life Events Checklist (LEC). The LEC (Weathers et al., 2013) is a 17-item self-report measure used to screen for respondents’ lifetime exposure to potentially traumatic events (e.g., combat, assault). The 17-items are difficult or stressful events (e.g., natural disaster, combat or exposure to a war-zone), and participants are asked to indicate one or more of the following: (a) happened to me; (b) witnessed it; (c) learned about it; (d) part of my job; (e) not sure; (f) doesn’t apply. The LEC is used to determine the type of trauma an individual experienced, and to determine if an individual’s PTSD was due to a single event or numerous traumatic experiences.

Trait Anxiety Inventory (TAI). The TAI (Spielberger, 1983) is a 20-item questionnaire that assesses how apprehensive or anxious a person feels in general, or most of the time. The TAI uses a 4-point Likert response format ranging from 1 (Almost Never) to 4 (Almost Always) to indicate how participants feel in response to phrases such as: “I feel pleasant”, “I feel like a failure”, and “I am confident”. The TAI test-retest reliabilities are high, ranging from 0.73-0.86

(Spielberger). The TAI has a potential range of 20-80, with the present sample ranging from 25-73 (see Table 2).

Beck Depression Inventory-II (BDI-II). The BDI-II (Beck et al., 1996) is a 21-item questionnaire designed to assess depression symptoms. Each item is rated on a 4-point Likert scale, with higher scores indicating more severe depression. The BDI-II displays high internal consistence (α = .92), validity, test-retest reliability (r = .93), and is highly correlated with self-reported and clinician ratings of depression (Beck et al., 1996; Beck, Steer, & Garbin, 1988). The present study used a 20-item BDI-II, omitting the potentially upsetting question associated with "Suicidal Thoughts or Wishes". The 20-item BDI-II has a potential range of 20-80, with the present sample ranging from 3 to 40 (see Table 2).

State Anxiety Inventory (SAI). The SAI (Spielberger, 1983) is a 10-item measure that was used to assess state anxiety before and following each condition. The 10-item SAI used in the present study consisted of the items: Calm, Relaxed, Presently worrying over possible misfortunes, Nervous, At ease, Jittery, Frightened, Worried, Steady, and Tense. Participants indicated how they felt at the time, using a 4-point Likert scale ranging from "Not at all" to "Very much so." This is a commonly used measure and the 10-item SAI (r = .95 with full 20-item inventory) has been recommended by Spielberger when multiple assessments are made and/or when time is a factor. The 10-item SAI has been validated in the literature, and shown acceptable internal consistencies (Cronbach's alphas between .84 - .92; Spielberger, 1979). Scores for the 10-item SAI can range from 10 to 40. For reliability, expressed as Cronbach's alphas, in the present study see Table 7.

Profile of Mood States (POMS). A shortened version of the original 65-item POMS (McNair, Lorr, &Droppleman, 1992), the POMS-SF (Shacham, 1983) was used to assess depression. Comprised of eight items, each item assessed how the participant felt at that moment on a 5-point scale (0 = not at all; 1 = a little; 2 = moderately; 3= quite a lot; 4= extremely). Thus, depression scores in the present study could range from 0 to 32, and consisted of the eight items; Unhappy, Sad, Blue, Hopeless, Discouraged, Miserable, Helpless, and Worthless. In the present study, depression scores ranged from 0 to 18. Additionally, baseline POMS were significantly correlated with the BDI-II (r_s= .54 - .84, $p_s < .01$). The 15-item POMS scale has been validated in the literature (Curran, Andrykowski & Studts, 1995). For reliability, expressed as Cronbach's alphas, in the present study see Table 7.

Activation-Deactivation Adjective Check List (AD ACL). The AD ACL (Thayer, 1986) is a 20-item measure, with five items comprising each of four subscales: Energy, Tiredness, Calmness, and Tension. Each item is rated on a 4-point rating scale (definitely feel = 4; definitely do not feel = 1; Thayer). Scores range from 5 to 20 for each of the four individual subscales listed above. The AD ACL has been validated in the literature (for psychometric information see Thayer 1978; 1986). For reliability, expressed as Cronbach's alphas, in the present study see Table 7.

Physical Activity Enjoyment Scale (PACES). The PACES (Kendzierski & DiCarlo, 1991) was used to assess enjoyment following each condition. The PACES consists of 18 bipolar statements that anchor the ends of a 7-point response scale where participants choose the number that most closely corresponds to the way they feel at the moment about the physical activity they have just finished doing [e.g., "I enjoy it (1) . . . I hate it (7)"; "I dislike it (1) . . . I like it (7)"]. Scores on the PACES can range from 18 to 126. Kendzierski and DeCarlo demonstrated that the PACES was valid and had acceptable internal consistencies in two separate studies (Cronbach's Alphas = 0.93 in both). For reliability, expressed as Cronbach's alphas, in the present study see Table 7.

Feeling Scale (FS). The FS (Hardy & Rejeski, 1989) is an 11-point, single-item, bipolar measure of pleasure-displeasure, which is commonly used for the assessment of affective valence responses during exercise (Ekkekakis & Petruzzello, 1999). The scale ranges from +5 to -5, with anchors provided at zero (Neutral) and at all odd integers, ranging from 'Very Good' (+5) to 'Very Bad' (-5).

Rating of Perceived Exertion (RPE). Perceptions of effort were assessed with the 15-point RPE scale (Borg, 1998). The RPE scale is commonly used for assessing perceived effort during exercise along a psychophysical continuum that ranges from 6 (no exertion at all) to 20 (maximal exertion). The RPE scale has been validated in the literature as a good way to assess exertion within an exercise setting (r = .884; Ueda & Kurokawa, 1991).

Heart Rate (HR). HR was continuously monitored using Polar© FT1 HR monitors and Polar WearLink Coded 31 transmitters (Polar Electro, Finland). Heart rate values were recorded and used for analysis, during all conditions, at minute 1.5, 3, 5, 6.5, 8, 10, 11.5, 13, 15, 16.5, 18, 20, 21.5, 23, 25, 26.5, 28, 30, 31.5, 33, and 35.

Data Analysis

Data analysis was conducted using SPSS 22.0.0 for Windows. Data were initially inspected for any unusual data points; as none were found, all participants were included in all analyses. Analysis of differences in the main outcome measures (anxiety, depression, energy, tiredness, calmness, tension) were done using a Condition [3: HIIE, MIA, SED] by Time [4: Pre, Post0, Post20, Post40 repeated measures analyses of variance [RM ANOVAs]. RPE and FS data were analyzed using a Condition [3: HIIE, MIA, SED] by Time [17: Pre, 3, 5, 8, 10, 13, 15, 18, 20, 23, 25, 28, 30, 33, Post0, Post20, Post40] RM ANOVAs. HR data were analyzed using a Condition [3: HIIE, MIA, SED] by Time [21:1.5, 3, 5, 6.5, 8, 10, 11.5, 13, 15, 16.5, 18, 20, 21.5, 23, 25, 26.5, 28, 30, 31.5, 33, 35] RM ANOVA. Finally, enjoyment (PACES) data were analyzed using a Condition [3: HIIE, MIA, SED] by Time [1: Post0] RM ANOVA]. Significant Condition, Time, and/or Condition x Time Interactions were further analyzed with repeated measures analyses of variance [RM ANOVA]. RM ANOVAs used the Bonferroni correction to protect against multiple comparisons. Effect sizes (*ES*s) were calculated as Cohen's *d* (Cohen, 1988). Effect sizes are reported as favorable (+) and unfavorable (-) changes.

Table 7

Cronbach's Alphas for AD ACL Subscales, State Anxiety, Depression, and Enjoyment

Condition	Time	Energy	Calm	Tense	Tired	SA	Dep	PACES
HIIE	Pre	.759	.797	.806	.883	.864	.903	
	Post0	.731	.720	.494	.661	.724	.875	.959
	Post20	.838	.724	.559	.785	.782	.829	
	Post40	.832	.859	.497	.719	.797	.898	
MIA	Pre	.750	.803	.845	.929	.906	.917	
	Post0	.761	.733	.682	.703	.688	.566	.913
	Post20	.843	.701	.708	.792	.818	.820	
	Post40	.786	.812	.685	.874	.847	.872	
SED	Pre	.807	.847	.792	.903	.870	.879	
	Post0	.741	.779	.659	.839	.871	.916	.919
	Post20	.827	.803	.723	.862	.856	.909	
	Post40	.851	.795	.870	.882	.872	.931	

CHAPTER 4

RESULTS

The primary purpose of the present study was to examine the feasibility of conducting an acute exercise study in a population with subsyndromal PTSD. To assess this, data were gathered on participant drop-out rates, adverse events experienced during exercise or submaximal VO_2 assessment, and failure to maintain adequate exercise intensity. One participant did not complete the required 4 sessions to be included in the present analysis. Upon contact, the participant indicated an injury that occurred outside of the ExPPL and was deemed unrelated to the present study. Further, there were no adverse events experienced during the submaximal VO_2 assessment, HIIE, MIA, or SED conditions. Finally, all participants were able to maintain the appropriate intensity during all exercise sessions [see below for HR & RPE data].

Anxiety

It was hypothesized that participants would experience significantly less anxiety post HIIE and MIA relative to SED. Examination of the Pre-to-Post affective changes in State Anxiety were initially done with a series of repeated measures [Condition (3: HIIE, MIA, SED) x Time (4: Pre, Post0, Post20, Post40)] ANOVAs with a Bonferroni adjustment for multiple comparisons. The Condition main effect was not significant [p= .739], but the Time main effect [F(1.82, 43.67)= 19.15, p< .001, η^2_{part} = .444; H-F ε= .606] was significant. However, this was superseded by a significant Condition x Time interaction [F(5.02, 120.56)= 2.79, p= .020, η^2_{part} = .104; H-F ε= .837]. To further explore the nature of the Condition x Time interaction, three individual Condition (2) x Time (4: Pre, Post0, Post20, Post40) RM ANOVAs were examined. There was a significant Condition x Time interaction for HIIE vs SED [*p*= .005], but not for HIIE vs MIA [*p*= .219], or MIA vs SED [*p*= .197]. It appears that the Condition (3: HIIE, MIA, SED) x Time (4: Pre, Post0, Post20, Post40) interaction above is driven by the relationship between HIIE and SED.

State Anxiety remained unchanged from Pre to Post0 HIIE [*p*= .377], was significantly reduced from Pre to Post20 [$M_{diff} \pm SE$; 3.72 ± 1.08; 95% CI: 1.50, 5.94; *p*= .002; Cohen's *d*= 0.84], and was significantly reduced from Pre to Post40 [$M_{diff} \pm SE$; 4.72 ± .99; 95% CI: 2.68, 6.76; *p*< .001; Cohen's *d*= 1.04; see Figure 1]. State Anxiety was significantly reduced Post0 MIA [$M_{diff} \pm SE$; 2.92 ± 1.24; 95% CI: .37, 5.47; *p*= .027; Cohen's *d*= .57], and remained significantly lower than Pre at Post20 [*p*= .001; Cohen's *d*= .84] and Post40 [*p*= .001; Cohen's *d*= .79; see Figure 1]. State Anxiety was significantly reduced Post0 SED [M_{diff} ± SE; 3.32 ± .67; 95% CI: 1.90, 4.74; *p*< .001; Cohen's *d*= .64], and remained significantly lower than Pre at Post20 [*p*< .001; Cohen's *d*= .70] and Post40 [*p*= .002; Cohen's *d*= .54; see Figure 1]. To further explore the change in State Anxiety across all time points, by condition, see Table 8.

As State Anxiety was significantly reduced immediately after MIA and SED (i.e., Post0, Post20, Post40), as well as after HIIE (i.e., Post20, Post40), further analysis on the individual components of the SAI was performed. A Condition [3: HIIE, MIA, SED] x Time [4: Pre, Post0, Post20, Post40] RM ANOVA on the individual items of 'At Ease', 'Jittery', 'Frightened', 'Worried', 'Calm', 'Nervous', 'Relaxed', 'Steady', 'Tense', and 'Worrying' was done (see Table 9). Immediately following both HIIE and MIA, cognitive apprehension items (i.e., 'Worrying' & 'Nervous') were significantly reduced while perceived activation items (i.e., 'Calm' & 'Relaxed') remained unchanged. Specifically, 'Worrying' was significantly reduced Post0 [*p*= .015; Cohen's *d*= .65], Post20 [*p*= .001; Cohen's *d*= .95], and Post40 [*p*= .001; Cohen's *d*= .95] relative to Pre

HIIE. ‘Nervous’ was reduced Post20 [*p*= .002; Cohen’s *d*= .68] and Post40 [*p*= .001; Cohen’s *d*= .78] relative to Pre HIIE. ‘Worrying’ was significantly reduced Post0 [*p*= .001; Cohen’s *d*= .74], Post20 [*p*= .004; Cohen’s *d*= .80], and Post40 [*p*= .028; Cohen’s *d*= .63], while ‘Nervous’ was reduced Post0 [*p*= .029; Cohen’s *d*= .61] relative to Pre MIA. Following SED, perceived activation items were significantly reduced while cognitive apprehension items remained unchanged. ‘Relaxed’ was significantly reduced Post0 [*p*= .016; Cohen’s *d*= .63] and Post20 [*p*= .028; Cohen’s *d*= .56] SED.

Table 8
Mean (± SD) and Effect Sizes Depression Before and After Exercise

Condition	Time	*M*	*SD*	Cohen's *d* Pre-Post0 Pre-Post20 Pre-Post40	Cohen's *d* Post0-Post20 Post0-Post40 Post20-Post40
HIIE	Pre	21.16	5.23		
	Post0	20.04	3.91	0.24	0.70*
	Post20	17.44	3.45	0.84*	0.95*
	Post40	16.44	3.69	1.04*	0.28*
MIA	Pre	21.16	6.26		
	Post0	18.24	3.60	0.57*	0.40*
	Post20	16.68	4.26	0.84*	0.35
	Post40	16.76	4.73	0.79*	-0.02
SED	Pre	21.04	5.50		
	Post0	17.72	4.89	0.64*	0.05
	Post20	17.48	4.58	0.70*	-0.10
	Post40	18.20	5.00	0.54*	-0.15

Note: Direction of effect size indicates favorable or unfavorable changes (e.g., -0.15 indicates worsening/increase in State Anxiety at Post40 relative to Post20 SED). * indicates significant differences between those time points (p ≤ .05).

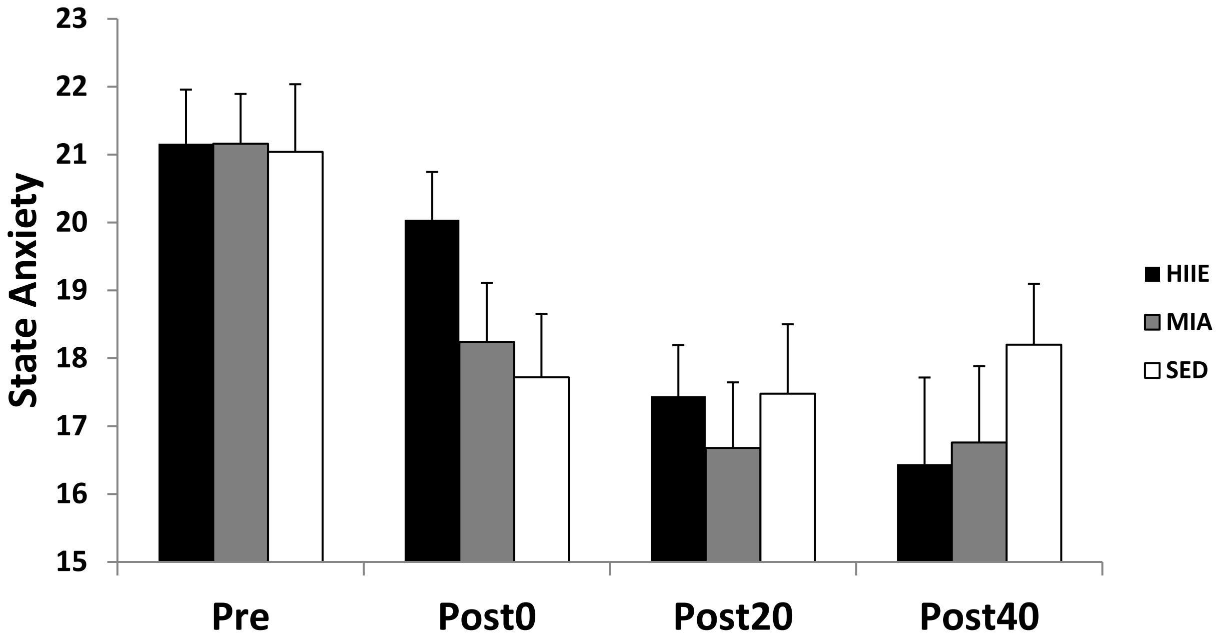


Figure 1. State Anxiety before and after each condition

Table 9
Means and Standard Deviations of Individual Items for SAI

Condition	Item	Pre		Post0		Post20		Post40	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
HIIE	Calm	2.84	0.99	2.76	1.01	2.36	0.64	2.16	0.90
	Relaxed	2.96	0.84	3.00	0.82	2.44	0.77	2.20[c,e]	0.77
	Worrying	1.72	0.74	1.28[a]	0.62	1.12[b]	0.50	1.12[c]	0.50
	Nervous	1.76	0.78	1.32	0.63	1.28[b]	0.62	1.24[c]	0.53
	At ease	2.76	0.78	2.84	0.85	2.12[b,d]	0.67	2.28	0.85
	Jittery	1.76	0.83	1.72	0.89	1.44	0.59	1.24[c]	0.53
	Frightened	1.08	0.22	1.00	0.00	1.00	0.00	1.04	0.20
	Worried	1.68	0.75	1.16	0.48	1.32	0.56	1.08[c]	0.28
	Steady	2.80	0.87	3.16	0.85	2.84	0.75	2.72	0.74
	Tense	1.80	0.71	1.80	0.77	1.44	0.65	1.28[c,e]	0.46
MIA	Calm	2.52	0.97	2.40	0.71	2.08	0.91	2.16	0.85
	Relaxed	2.88	0.93	2.52	0.97	2.28[b]	1.02	2.24[c]	1.01
	Worrying	1.92	0.81	1.40[a]	0.58	1.36[b]	0.57	1.44[c]	0.71
	Nervous	1.72	0.74	1.32[a]	0.56	1.44	0.65	1.32	0.56
	At ease	2.44	0.87	2.56	0.77	2.12	0.93	2.28	1.02
	Jittery	1.92	1.00	1.60	0.82	1.24[b]	0.53	1.20[c]	0.50
	Frightened	1.20	0.41	1.04	0.20	1.08	0.28	1.00	0.00
	Worried	1.88	1.02	1.20[a]	0.50	1.12[b]	0.44	1.32[c]	0.56
	Steady	2.80	0.87	2.80	0.71	2.60	0.82	2.52	1.01
	Tense	1.88	0.84	1.40	0.71	1.36[b]	0.57	1.28[c]	0.54
SED	Calm	2.60	0.96	2.24	0.93	2.16	0.80	2.40	0.82
	Relaxed	2.76	0.78	2.28[a]	0.74	2.28[b]	0.94	2.52	1.01
	Worrying	1.88	0.93	1.68	0.75	1.60	0.77	1.64	0.76
	Nervous	1.64	0.81	1.48	0.66	1.40	0.65	1.40	0.82
	At ease	2.76	0.97	2.16[a]	0.90	2.24[b]	0.78	2.20[c]	0.82
	Jittery	1.60	0.82	1.28	0.46	1.24[b]	0.44	1.32[c]	0.63
	Frightened	1.20	0.50	1.00	0.00	1.00	0.00	1.00	0.00
	Worried	1.72	0.79	1.48	0.83	1.32[b]	0.56	1.48	0.66
	Steady	2.96	0.74	2.60[a]	0.77	2.72	0.85	2.72	0.79
	Tense	1.92	0.76	1.52[a]	0.72	1.52	0.72	1.52[c]	0.72

[a] Significant change from Pre-to Post0. [b] Significant change from Pre-to Post20. [c] Significant change from Pre-to Post40. [d] Significant change from Post0-to Post20. [e] Significant change from Post0-to Post40. [f] Significant change from Post20-to Post40.

Depression

It was hypothesized that participants would experience significantly less Depression post HIIE and MIA relative to SED. Examination of the Pre-to-Post affective changes in

Depression were initially done with a [Condition (3: HIIE, MIA, SED) x Time (4: Pre, Post0, Post20, Post40)] RM ANOVA with a Bonferroni adjustment for multiple comparisons. The Condition main effect was not significant [p= .495], but the Time main effect [F(1.26, 30.23)= 19.96, p< .001, η^2_{part} = .454; H-F ε= .420] was significant. However, this was superseded by a significant Condition x Time interaction [F(3.37, 80.89)= 3.35, p= .019, η^2_{part} = .122; H-F ε= .562. To further explore the nature of the Condition x Time interaction, three individual Condition (2) x Time (4: Pre, Post0, Post20, Post40) ANOVAs were examined. There was a significant Condition x Time interaction for MIA vs SED [p= .016], but not for HIIE vs MIA [p= .105], or HIIE vs SED [p= .178]. It appears that the Condition (3: HIIE, MIA, SED) x Time (4: Pre, Post0, Post20, Post40) interaction above is driven by the relationship between MIA and SED.

For HIIE, Depression was significantly decreased relative to Pre, at Post0 [$M_{diff} \pm SE$; 1.96 ± .97; 95% CI: -.04, 3.96; p= .054; Cohen's d= .50], Post20 [$M_{diff} \pm SE$; 2.88 ± .90; 95% CI: 1.03, 4.73; p= .004; Cohen's d= .82], and Post40 [$M_{diff} \pm SE$; 2.72 ± .90; 95% CI: .86, 4.58; p= .006; Cohen's d= .77; see Figure 2]. Similarly, for MIA, Depression was significantly decreased at Post0 [$M_{diff} \pm SE$; 3.96 ± .88; 95% CI: 2.14, 5.79; p< .001; Cohen's d= 1.03], and remained significantly less than Pre at Post20 [p< .001; Cohen's d= 1.00] and Post40 [p< .001; Cohen's d= .83; see Figure 2]. For SED, Depression decreased significantly from Pre to Post0 [$M_{diff} \pm SE$; 1.28 ± .41; 95% CI: .44, 2.12; p= .004; Cohen's d= .34], and remained significantly less than Pre at Post20 [p= .002; Cohen's d= .40] and Post40 [p= .013; Cohen's d= .33; see Figure 2]. To further explore the change in Depression across all time points, by condition, see Table 10.

Table 10
Mean (± SD) and Effect Sizes Depression Before and After Exercise

Condition	Time	*M*	*SD*	Cohen's *d* Pre-Post0 Pre-Post20 Pre-Post40	Cohen's *d* Post0-Post20 Post0-Post40 Post20-Post40
HIIE	Pre	4.08	4.40		
	Post0	2.12	3.42	0.50*	0.32*
	Post20	1.20	2.27	0.82*	0.26*
	Post40	1.36	2.33	0.77*	-0.07
MIA	Pre	4.64	5.31		
	Post0	0.68	1.18	1.03*	0.00
	Post20	0.68	1.73	1.00*	-0.27
	Post40	1.20	2.48	0.83*	-0.24*
SED	Pre	3.44	4.14		
	Post0	2.16	3.39	0.34*	0.07
	Post20	1.92	3.33	0.40*	0.00
	Post40	2.16	3.66	0.33*	-0.07

Note: Direction of effect size indicates favorable or unfavorable changes (e.g., -0.27 indicates worsening/increase in Depression at Post40 relative to Post0 MIA). * indicates significant differences between those time points ($p \leq .05$).

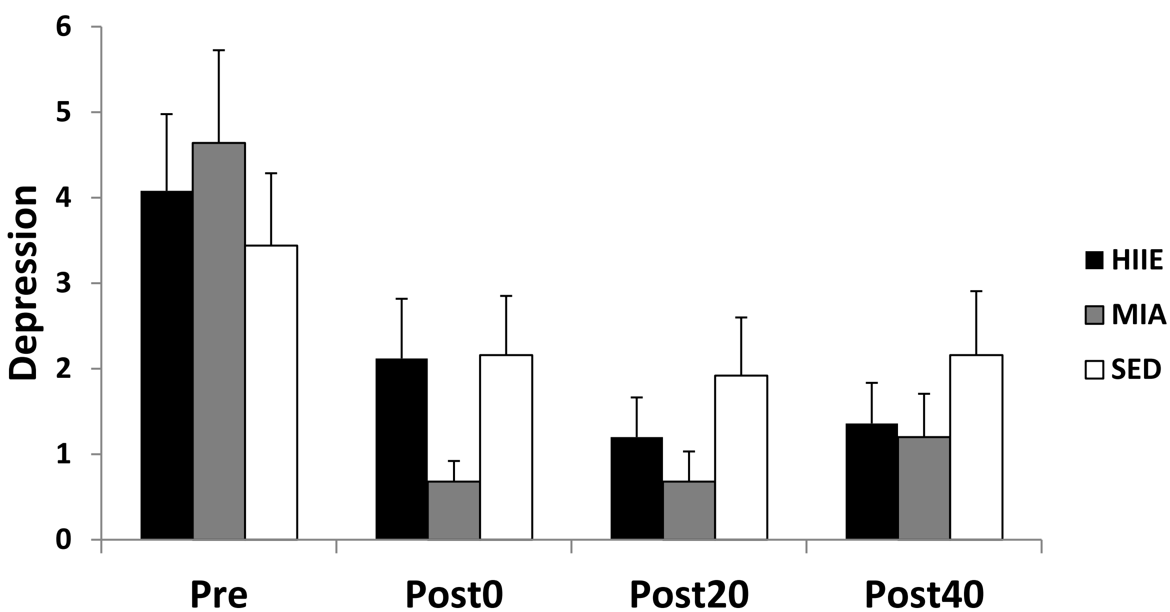


Figure 2. Depression before and after each condition.

Enjoyment

It was also hypothesized that post-condition enjoyment would be similar following both HIIE and MIA. Participants completed the PACES immediately after all three conditions, with scores ranging from 50 to 126 [$M \pm SD$; 92.12 ± 22.03] for the HIIE condition, 69 to 126 [$M \pm SD$; 98.24 ± 15.23] for the MIA condition, and 42 to 120 [$M \pm SD$; 75.04 ± 16.89] for the SED condition**.** To assess whether there were differences in enjoyment, a Condition [3: HIIE, MIA, SED] RM ANOVA with a Bonferroni adjustment for multiple comparisons was performed. HIIE was not different from MIA [p= .390], but resulted in significantly more enjoyment relative to SED [$M_{diff} \pm SE$; 17.08 ± 5.59; 95% CI: 2.70, 31.46; p= .016; Cohen's d= .87]. Further, MIA resulted in significantly more enjoyment than SED [$M_{diff} \pm SE$; 23.20 ± 4.37; 95% CI: 11.97, 34.43; p< .001; Cohen's d= 1.44; see Figure 3].

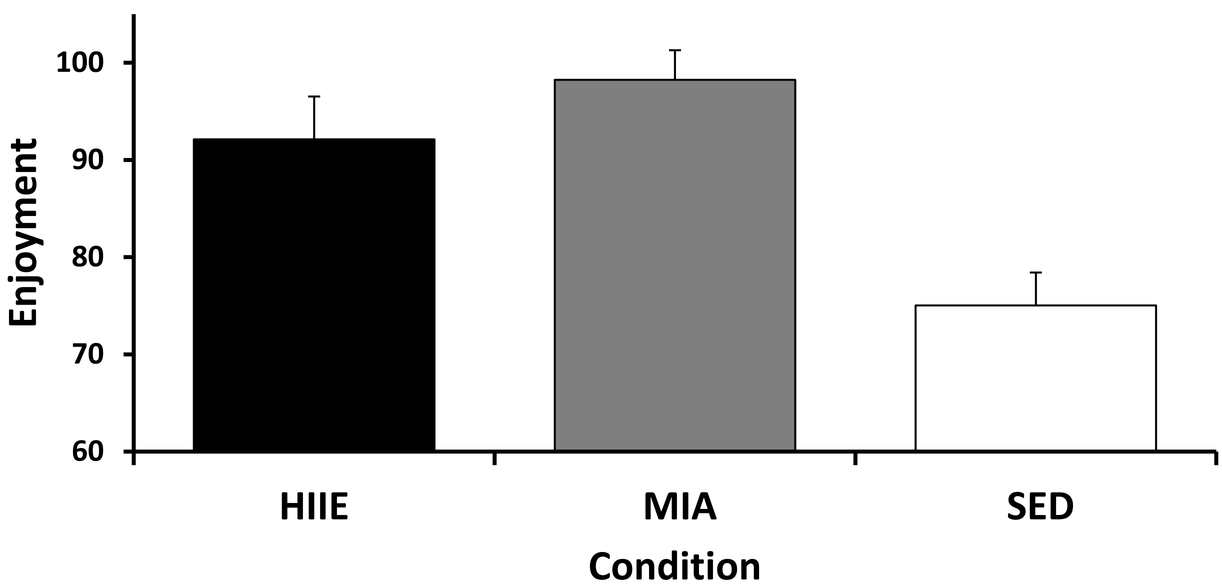


Figure 3. Post exercise enjoyment between all three conditions.

Affective Valence

Pre-to-post affective valence was assessed via Feeling Scale [FS] measures collected before, Post0, Post20, and Post40 for each condition. Analysis of FS was initially done with a Condition [3: HIIE, MIA, SED] x Time [4: Pre, Post0, Post20, Post40] RM ANOVA with a Bonferroni adjustment for multiple comparisons. The Condition [$p= .066$] effect was not significant, but the Time [$F(2.18, 52.41)= 13.05$, $p< .001$, $\eta^2_{part} = .352$; H-F $\varepsilon= .728$] effect was significant. However, this was superseded by a significant Condition x Time interaction [$F(4.09, 98.10)= 6.01$, $p< .001$, $\eta^2_{part} = .200$; H-F $\varepsilon= .681$]. Participants reported greater FS scores at Post40 [$M_{diff} \pm SE$; 1.40 ± .40; 95% CI: .57, 2.23; $p= .002$; Cohen's $d= .82$] relative to Pre in HIIE. For MIA, participants reported greater FS scores by Post20 [$M_{diff} \pm SE$; 1.28 ± .35; 95% CI: .55, 2.01; $p= .001$; Cohen's $d= .82$]; FS scores remained greater at Post 40 [$p= .003$; Cohen's $d= .70$]. For SED, FS was significantly greater by Post0 [$M_{diff} \pm SE$; 1.04 ± .29; 95% CI: .44, 1.64; $p= .002$; Cohen's $d= .54$], and remained greater at Post 20 [$p= .001$; Cohen's $d= .60$] and Post 40 [$p= .013$; Cohen's $d= .54$; see Table 11 & Figure 4].

Table 11
Mean (± SD) and Effect Sizes Feeling Scale Before and After Exercise

Condition	Time	*M*	*SD*	Cohen's *d* Pre-Post0 Pre-Post20 Pre-Post40	Cohen's *d* Post0-Post20 Post0-Post40 Post20-Post40
HIIE	Pre	2.32	2.08		
	Post0	1.64	1.78	-0.35	0.82*
	Post20	3.04	1.65	0.38	1.36*
	Post40	3.72	1.24	0.82*	0.47*
MIA	Pre	2.60	1.80		
	Post0	3.24	1.09	0.43	0.54*
	Post20	3.88	1.27	0.82*	0.40
	Post40	3.76	1.51	0.70*	-0.09
SED	Pre	2.36	2.14		
	Post0	3.40	1.68	0.54*	0.05
	Post20	3.48	1.58	0.60*	0.00
	Post40	3.40	1.71	0.54*	-0.05

Note: Direction of effect size indicates favorable or unfavorable changes (e.g., -0.35 indicates worsening/decrease in affective valence at Post0 relative to Pre HIIE). * indicates significant differences between those time points ($p \leq .05$).

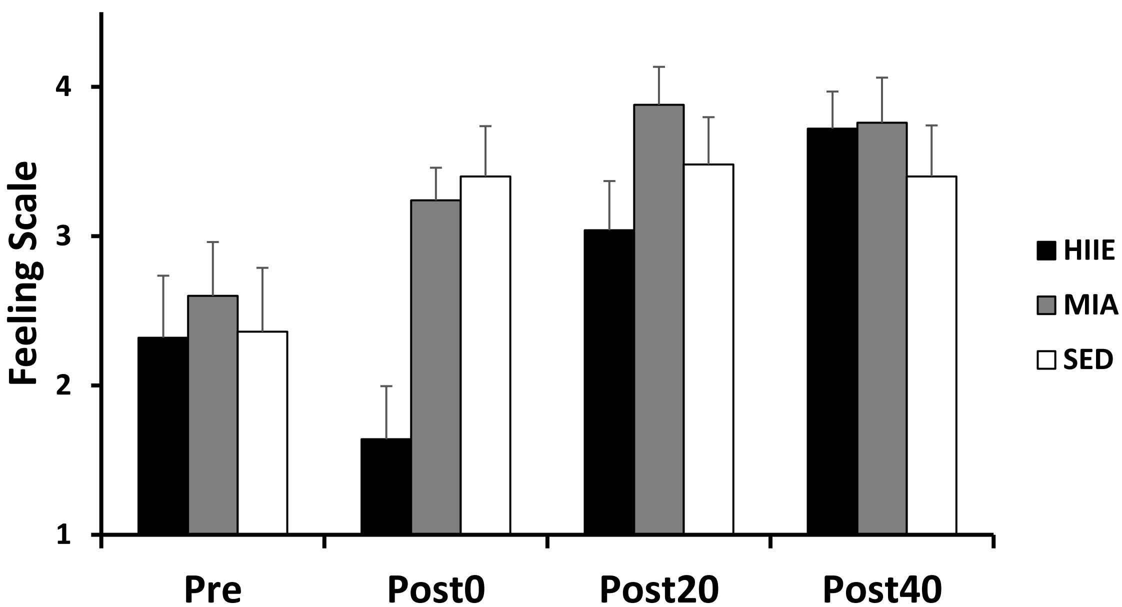


Figure 4. Feeling Scale before and after each condition.

To further understand the nature of in-task affective valence, during HIIE, FS was assessed after each 3-minute interval (FS_a) and after each 2-minute rest period (FS_b). Two RM ANOVAs were done: (1) [Condition (3: HIIEa, MIA, SED) x Time (4: 8-min, 13-min, 18-min, 23-min, 28-min)], and (2) [Condition (3: HIIEb, MIA, SED) x Time (4: 10-min, 15-min, 20-min, 25-min, 30-min)]. For a complete picture of affective valence from Pre, during, and post each condition, see Figure 5. For FS assessed immediately after each 3-minute interval, in-task affective valence was significantly less positive during HIIE relative to both MIA [$M_{diff} \pm SE$; 1.61 ± .33; 95% CI: .76, 2.46; p< .001; Cohen's d= 1.14] and SED [$M_{diff} \pm SE$; 2.42 ± .51; 95% CI: 1.11, 3.74; p= .001; Cohen's d= 1.41; see Figure 6, top panel]. For FS assessed immediately after each 2-minute rest period, in-task affective valence was significantly less positive during HIIE relative to MIA [$M_{diff} \pm SE$; .70 ± .26; 95% CI: .02, 1.37; p= .042; Cohen's d= .62] and was significantly less positive relative to SED [$M_{diff} \pm SE$; 1.51 ± .39; 95% CI: .51, 2.51; p= .002; Cohen's d= 1.02; see Figure 6, bottom panel].

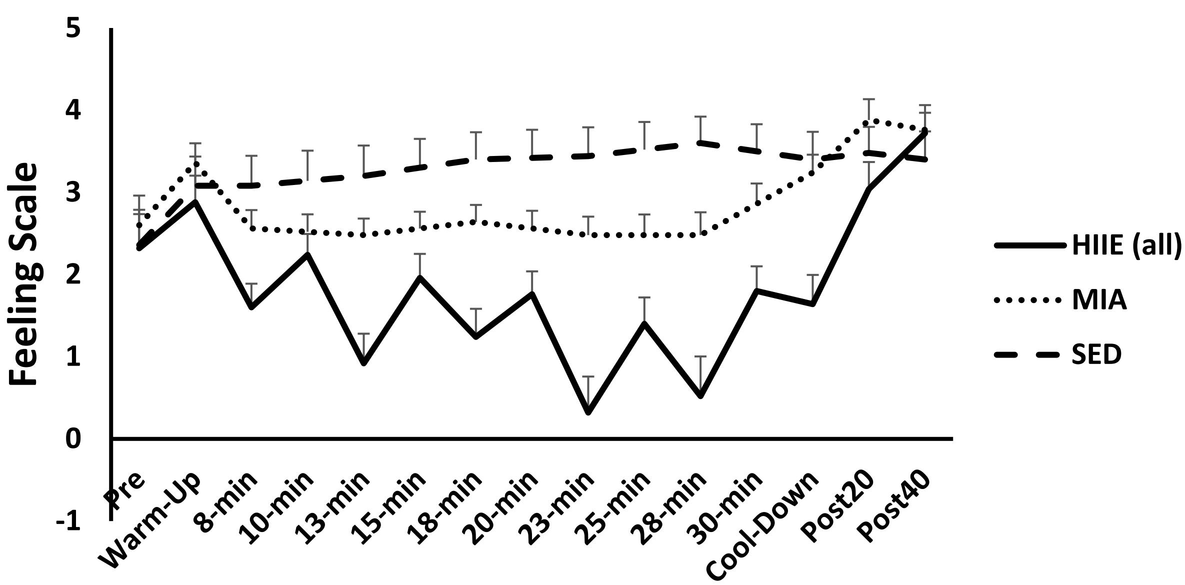
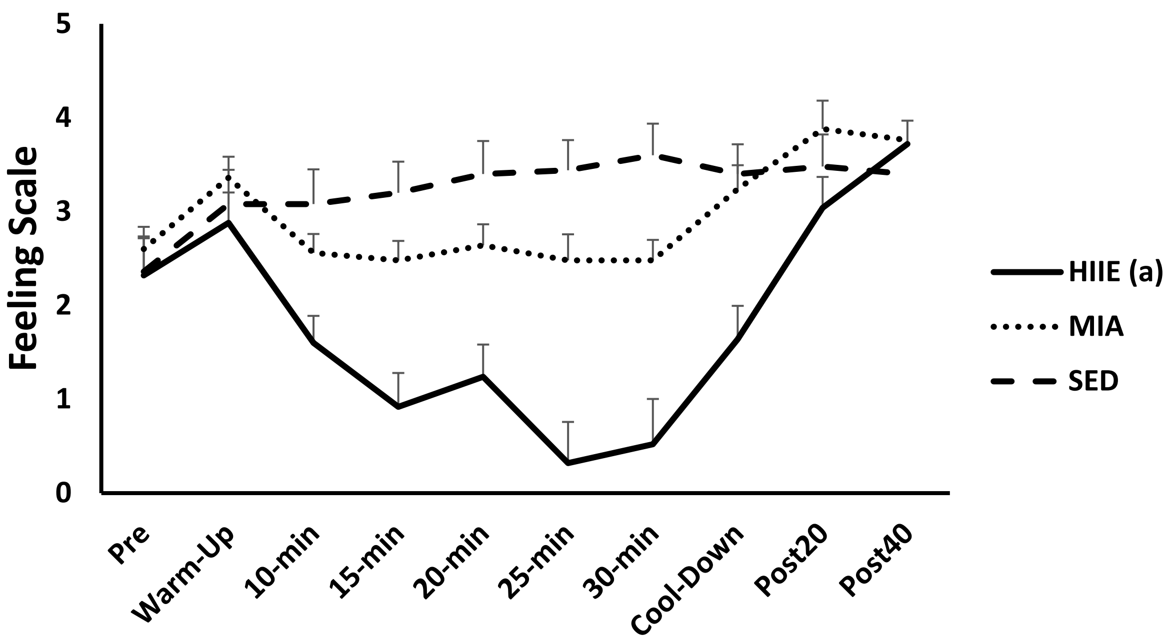


Figure 5. Feeling Scale values across time for each condition.



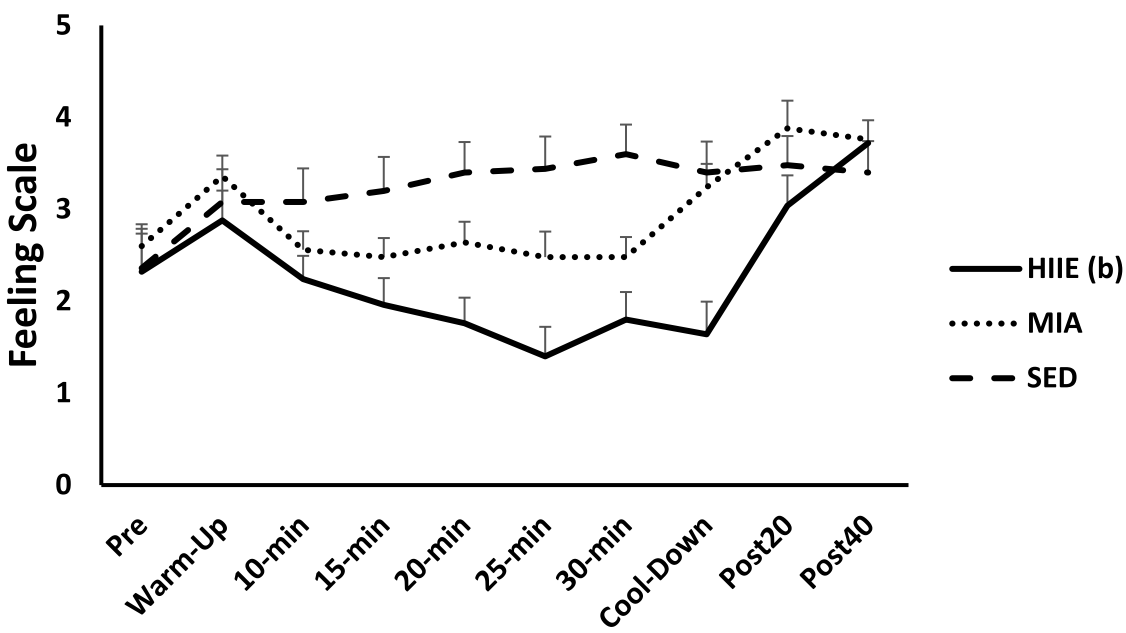


Figure 6. Feeling Scale scores for FSa assessed after exercise intervals (*top*) and for FSb assessed after rest periods (*bottom*).

Finally, it was hypothesized that participants would show an increase in positive affect and a decrease in negative affect following both HIIE and MIA relative to SED. To test this hypothesis, a series of repeated measures [Condition (3: HIIE, MIA, SED) x Time (4: Pre, Post0, Post20, Post40)] ANOVAs for the four subscales of the AD ACL [Energy, Tiredness, Tension, Calmness] were done.

For Energy [see Figure 7, top panel], there was a significant Condition [$F(2, 48)= 10.52$, $p< .001$, $\eta^2_{part} = .305$; H-F ε= 1.0] and Time [$F(2.5, 39.0)= 10.82$, $p< .001$, $\eta^2_{part} = .311$; H-F ε= .846; see Table 12] main effect, but this was superseded by a significant Condition x Time interaction [$F(5.9, 141.5)= 10.32$, $p< .001$, $\eta^2_{part} = .301$; H-F ε=9.83]. Specifically, Energy was significantly greater Post0 both HIIE [$M_{diff} \pm SE$; 2.80 ± .68; 95% CI: 1.41, 4.20; $p< .001$; Cohen's $d= .94$] and MIA [$M_{diff} \pm SE$; 2.84 ± .59; 95% CI: 1.62, 4.06; $p< .001$; Cohen's $d= .95$], while Energy was significantly reduced Post0 SED [$M_{diff} \pm SE$; 1.16 ± .40; 95% CI: .33, 1.99; $p= .008$; Cohen's $d= -.39$]. As such, Energy was significantly greater following HIIE [$p= .004$; Cohen's $d= .74$] and MIA [$p= .001$; Cohen's $d= .67$] relative to SED.

For Tiredness [see Figure 7, bottom panel], there was a significant Condition main effect [$F(1.8, 43.8)= 4.00$, $p= .029$, $\eta^2_{part} = .143$; H-F ε= .91; see Table 12], but the Time main effect [$p= .324$] and Condition x Time interaction [$p= .062$] were not significant. Tiredness significantly decreased Post0 MIA [$M_{diff} \pm SE$; 1.64 ± .60; 95% CI: .41, 2.87; $p= .011$; Cohen's $d= .48$], and remained unchanged Post0 HIIE [$p= .745$] and SED [$p= .555$]. As such, Tiredness was significantly lower throughout MIA relative to SED and HIIE [$M_{diff} \pm SE$; 1.45 ± .40; 95% CI: .43, 2.47; $p= .004$; Cohen's $d= .46$].

Table 12
Mean (± SD) and Effect Sizes Energy and Tiredness Before and After Exercise

Measure	Condition	Time	*M*	*SD*	Cohen's d Pre-Post0 Pre-Post20 Pre-Post40	Cohen's d Post0-Post20 Post0-Post40 Post20-Post40
Energy	HIIE	Pre	10.12	2.67		
		Post0	12.92	3.24	0.94*	-0.63*
		Post20	10.80	3.49	0.22	-0.88*
		Post40	10.16	3.00	0.01	-0.20
	MIA	Pre	9.88	2.99		
		Post0	12.72	3.02	0.94*	-0.52*
		Post20	10.96	3.67	0.32*	-0.86*
		Post40	10.04	3.22	0.05	-0.27*
	SED	Pre	9.92	3.09		
		Post0	8.76	2.82	-0.39*	-0.03
		Post20	8.68	2.97	-0.41*	-0.40
		Post40	8.72	3.12	-0.39*	0.01
Tiredness	HIIE	Pre	10.92	3.76		
		Post0	10.68	2.97	0.07	0.00
		Post20	10.68	3.20	0.07	0.04
		Post40	10.56	2.97	0.11	0.04
	MIA	Pre	10.92	4.10		
		Post0	9.28	2.64	0.48*	-0.05
		Post20	9.44	3.25	0.40*	-0.17
		Post40	9.76	3.44	0.31	-0.10
	SED	Pre	11.28	4.08		
		Post0	10.96	3.27	0.09	-0.27*
		Post20	11.88	3.66	-0.16	-0.04
		Post40	11.08	3.29	0.05	0.23*

Note: Direction of effect size indicates favorable or unfavorable changes (e.g., -0.63 indicates worsening/decrease in Energy at Post20 relative to Post0 HIIE). * indicates significant differences between those time points ($p \leq .05$).

For Calmness [see Figure 8, top panel], the Condition effect was not significant [*p*= .076] but the Time effect [$F(2.8,67.1)= 8.66$, $p< .001$, $\eta^2_{part} = .265$; H-F ε= .93; see Table 13] was significant. This was superseded by a significant Condition x Time interaction [$F(4.9, 118.7)= 3.80$, $p= .003$, $\eta^2_{part} = .137$; H-F ε= .82]. While Calmness showed no change Pre to Post0 HIIE [*p*=

.252] and MIA [*p*= .446], Calmness was significantly increased from baseline by Post20 HIIE [$M_{diff} \pm SE$; 1.56 ± .66; 95% CI: .19, 2.93; *p*= .027; Cohen's *d*= .49] and by Post40 MIA [$M_{diff} \pm SE$; 1.72 ± .68; 95% CI: .32, 3.12; *p*= .018; Cohen's *d*= .50]. Calmness was significantly increased Post0 SED [$M_{diff} \pm SE$; 1.76 ± .57; 95% CI: .59, 2.93; *p*= .005; Cohen's *d*= .50] and remained significantly increased at Post20 [*p*= .001; Cohen's *d*= .49] and Post40 [*p*= .030; Cohen's *d*= .39].

For Tension [see Figure 8, bottom panel], the Condition effect was not significant [*p*= .380], but there was a significant Time main effect [F(1.8, 43.6)= 14.75, p< .001, η^2_{part} = .381; H-F ε= .61; see Table 13]. This was superseded by a significant Condition x Time interaction [F(4.4, 106.2)= 4.66, p= .001, η^2_{part} = .163; H-F ε= .74]. Specifically, Tension was significantly reduced by Post40 HIIE [$M_{diff} \pm SE$; 1.76 ± .55; 95% CI: .63, 2.89; *p*= .004; Cohen's *d*= .78], and by Post0 MIA [$M_{diff} \pm SE$; 1.60 ± .61; 95% CI: .34, 2.86; *p*= .015; Cohen's *d*= .62] and SED [$M_{diff} \pm SE$; 1.48 ± .36; 95% CI: .74, 2.22; *p*< .001; Cohen's *d*= .62].

Table 13
Mean (± SD) and Effect Sizes Calmness and Tension Before and After Exercise

Measure	Condition	Time	*M*	*SD*	Cohen's d Pre-Post0 Pre-Post20 Pre-Post40	Cohen's d Post0-Post20 Post0-Post40 Post20-Post40
Calmness	HIIE	Pre	10.12	3.36		
		Post0	9.12	2.88	-0.32	0.88*
		Post20	11.68	2.97	0.49*	-0.88*
		Post40	12.00	3.61	0.54*	0.10
	MIA	Pre	10.92	3.19		
		Post0	10.40	2.58	-0.18	0.48*
		Post20	11.84	3.36	0.28	-0.71*
		Post40	12.64	3.66	0.50*	0.23
	SED	Pre	10.68	3.64		
		Post0	12.44	3.48	0.50*	0.00
		Post20	12.44	3.57	0.49*	-0.12
		Post40	12.04	3.43	0.39*	-0.11
Tension	HIIE	Pre	8.04	2.79		
		Post0	8.44	2.12	-0.16	0.94*
		Post20	6.68	1.57	0.60	1.16*
		Post40	6.28	1.57	0.78*	0.26
	MIA	Pre	8.40	3.07		
		Post0	6.80	2.02	0.62*	0.31
		Post20	6.24	1.61	0.88*	0.59*
		Post40	5.80	1.32	1.10*	0.30*
	SED	Pre	8.12	2.76		
		Post0	6.64	1.96	0.62*	-0.08
		Post20	6.80	2.00	0.55*	0.07
		Post40	6.80	2.53	0.50*	0.00

Note: Direction of effect size indicates favorable or unfavorable changes (e.g., -0.16 indicates worsening/increase in Tension at Post0 relative to Pre HIIE). * indicates significant differences between those time points ($p \leq .05$).

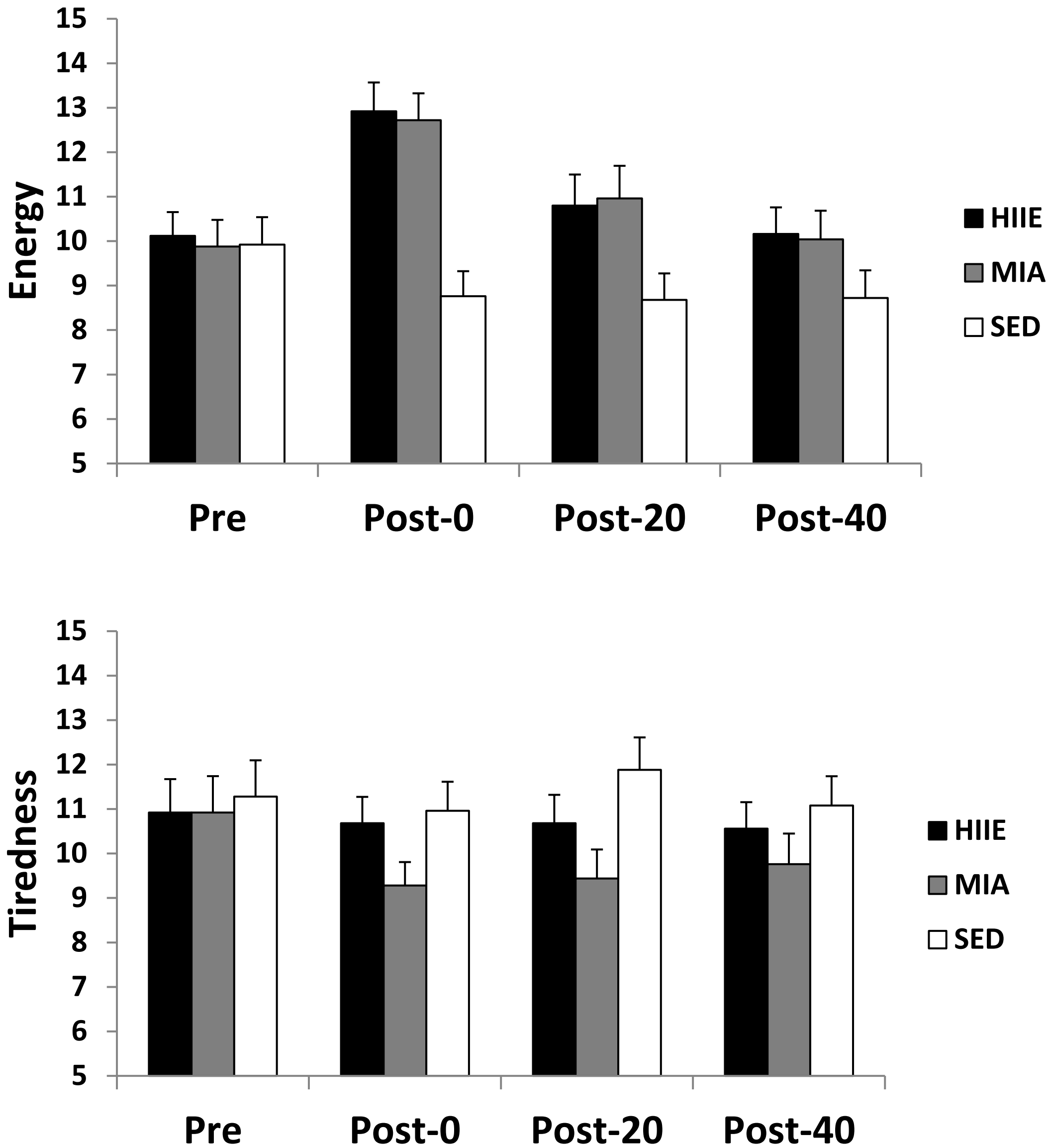


Figure 7. AD ACL scores for Energy (*top*) and Tiredness (*bottom*) subscales Pre- and post-exercise.

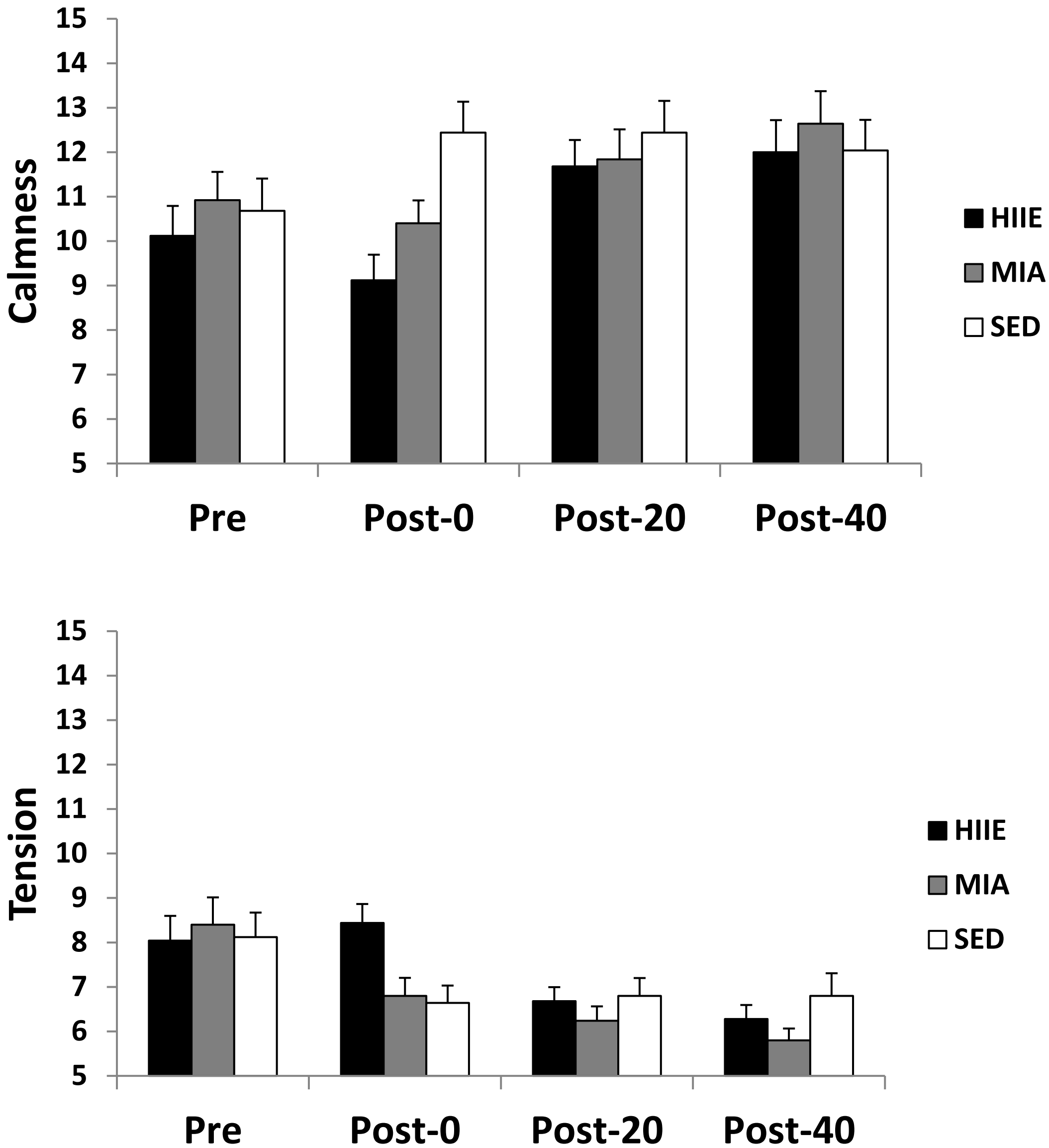


Figure 8. AD ACL scores for Calmness (*top*) and Tension (*bottom*) subscales Pre- and post-exercise.

Manipulation Check

During each condition, ratings of perceived exertion and physiological respones (i.e., Heart Rate) were measured. By design, the HIIE condition should have been perceived as the most intense condition, followed by MIA and then SED. Heart rate responses should mimic this pattern. To assess changes in RPE, a Condition [3: HIIE, MIA, SED] x Time [7: 5-min, 10-min, 15-min, 20-min, 25-min, 30-min, 35-min] RM ANOVA was performed. The Condition ($p < .001$), Time ($p < .001$), and Condition x Time interaction [$F(7.8, 187.8) = 53.92$, $p < .001$, $\eta^2_{part} = .692$; H-F $\varepsilon = .652$; see Figure 9, top panel] were all significant. Specifically, RPE was significantly higher during HIIE relative to both MIA [$M_{diff} \pm SE$; 2.53 ± .32; CI: 1.72, 3.34; $p < .001$] and SED [$M_{diff} \pm SE$; 7.61 ± .25; CI: 6.98, 8.25; $p < .001$] conditions. Additionally, RPE was significantly higher during MIA relative to SED [$M_{diff} \pm SE$; 5.08 ± .29; CI: 4.35, 5.81; $p < .001$].

Heart rate was assessed every 90 seconds during each condition. There was a significant Condition [$p < .001$], Time [$p < .001$], and Condition x Time interaction [$F(14.5, 348.6) = 105.71$, $p < .001$, $\eta^2_{part} = .815$; H-F $\varepsilon = .363$; see Figure 9, bottom panel]. Heart rate was not different between HIIE and MIA [$p = 1.00$], but participants had significantly higher heart rates during HIIE [$M_{diff} \pm SE$; 68.97 ± 2.09; CI: 63.59, 74.36; $p < .001$] and MIA [$M_{diff} \pm SE$; 68.55 ± 2.45; CI: 62.24, 74.85; $p < .001$] relative to SED. Additionally, heart rate assessed during and immediately following interval periods of HIIE was significantly higher relative to heart rate during MIA [$M_{diff} \pm SE$; 10.35 ± 1.99; CI: 6.24, 14.45; $p < .001$].

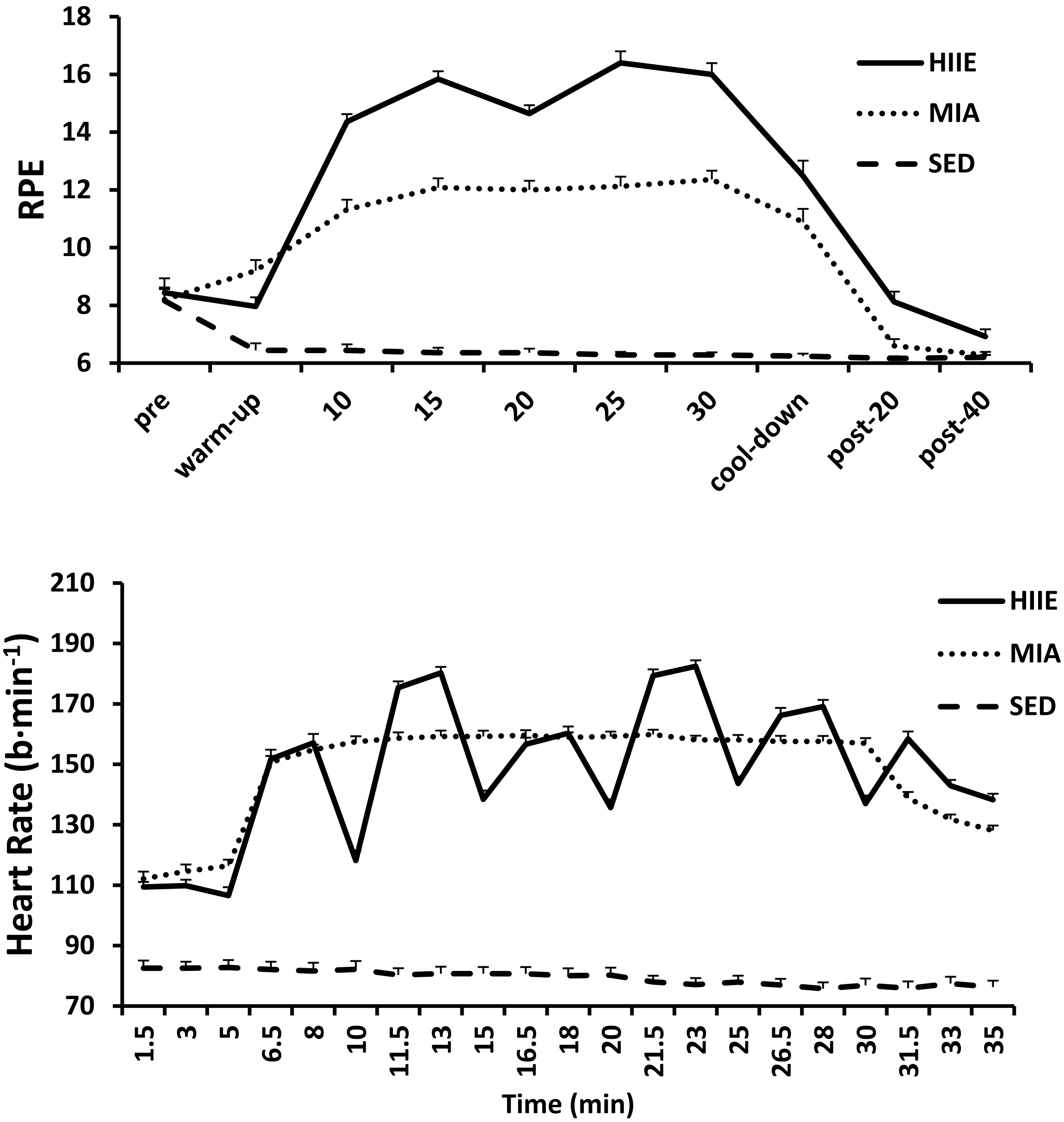


Figure 9. In-task assessment of Rating of Perceived Exertion (*top*) and Heart Rate (*bottom*).

CHAPTER 5

DISCUSSION

Previous research has shown exercise interventions to be effective in reducing symptoms of Post-Traumatic Stress Disorder (PTSD), as well as decreasing the prevalence of comorbid conditions associated with PTSD. Exercise has been successful in significantly decreasing symptoms of PTSD following treadmill-based interventions (Manger & Motta, 2005; Powers et al., 2015), stationary cycling (Fetzner & Asmundson, 2014), group-based exercise (Newman & Motta, 2007), walking interventions (Diaz & Motta, 2008), and supervised resistance exercise (Rosenbaum et al., 2014). However, what has been overlooked, to date, is the acute psychological responses to various modes of exercise. Specifically, in-task affective valence (i.e., Feeling Scale), Pre-to-Post affective response (i.e., energy, tiredness, tension, calmness, state anxiety, depression) and enjoyment of each individual exercise session. With clinical populations, arguably the most important component of any intervention is continued participation. With previous research highlighting the beneficial effect of numerous modes of exercise, it is equally important to understand the acute psychological effects of these exercise modes. This can lead to a much more in-depth understanding of exercise adherence and long-term sustainable effects.

The primary purpose of the present study was to determine if an acute bout of HIIE and/or MIA is feasible within a population living with subsyndromal PTSD. The results support the notion that exercise is a safe and viable option for individuals living with subsyndromal PTSD. First, there were no adverse events reported during any of the exercise conditions or during the estimated VO_{2peak} treadmill test. Of the 26 participants that were recruited, 25 completed all 4 sessions, and the one dropout was due to an injury that occurred outside of, and was unrelated to, the present study. Additionally, participants reported positive affective valence during both HIIE and MIA as well as relatively high levels of enjoyment following both HIIE and MIA. They were also able to maintain an adequate intensity during both HIIE and MIA.

It was hypothesized that participants would report significantly less anxiety following both HIIE and MIA relative to the SED condition. The results did not support this hypothesis as state anxiety was significantly reduced immediately following both MIA and SED, but not HIIE. However, HIIE did not increase state anxiety at Post0, and state anxiety was significantly reduced at Post20 and Post40 relative to Pre. The reduction in state anxiety immediately following MIA is consistent with previous meta-analytical research highlighting the immediate anxiolytic effects of moderate intensity aerobic exercise (Ensari, et al., 2015; Petruzzello et al., 1991). While state anxiety changes associated with HIIE remain relatively unexplored, the present results are supported by literature examining the acute changes in anxiety following high-intensity anaerobic exercise. Greene and Petruzzello (2014) found state anxiety to be significantly reduced 20-minutes following high-intensity resistance exercise (i.e., anaerobic), while anxiety was not different immediately after exercise. Additionally, state anxiety has been shown to be reduced following no-exercise control conditions, in which participants felt they experienced something positive (Parente, 2000). While not significant, there was a larger anxiolytic effect at Post40 following both HIIE and MIA relative to SED, but the anxiolytic effects occurred faster following MIA and SED relative to HIIE.

As there were no significant differences in state anxiety between HIIE or MIA and SED, follow-up analysis on the individual components of the SAI were examined. As the SAI measures components of perceived activation (i.e., anxiety-absent items), and exercise has been shown to increase perceived activation (Ekkekakis, Hall, & Petruzzello, 1999), examination of cognitive antecedents/apprehension and perceived activation/effort-related tension items was undertaken. The SAI items most representative of cognitive apprehension are (1) “Presently worrying over possible misfortunes” and (2) “Nervous”, while the items most commonly associated with perceived activation are (1) “Calm” and (2) “Relaxed” (Spielberger, 1983). Interestingly, cognitive apprehension was significantly reduced Post0, Post20, and Post40 MIA and HIIE, while there was no significant change in cognitive apprehension (i.e., Nervous & Worrying) at any point for SED. Additionally, perceived activation (i.e., Calm & Relaxed) significantly decreased Post0 and Post20 SED, while perceived activation showed no change at Post0 or Post20 HIIE and MIA. It appears the driving force behind the reduction in state anxiety observed Post0 SED, stems from a significant decrease in perceived activation and not what Spielberger identified as the main component of anxiety (i.e., cognitive appraisal). Likewise, the reduction of cognitive apprehension in HIIE is not reflected at Post0 due to small increases in other effort-related tension items (e.g., decreased scores for; at Ease, Relaxed, & Steady). The psychometric confounds associated with the SAI and high-intensity exercise have been supported in the literature (Ekkekakis et al.; Rejeski, Hardy, & Shaw, 1991).

Similar to anxiety, it was hypothesized that depression would be significantly reduced following HIIE and MIA relative to SED. While depression was significantly reduced following HIIE and MIA, it was similarly reduced following SED. These effects were evident throughout the 40-minute recovery period. While the results do not fully support the hypothesis, the present findings are consistent with previous literature examining the acute changes in depression in individuals diagnosed with MDD. Bartholomew, Morrison, and Ciccolo (2005) reported a significant reduction in depression following both 30-minutes of rest and 30-minutes of moderate intensity aerobic exercise. Additionally, there was a trend for larger improvements associated with HIIE and MIA relative to SED in the present study, although not statistically significant. Further, while at Post40 there was no difference between HIIE and MIA, it appears the reduction in depression occurs faster following MIA relative to HIIE. Additionally, baseline depression scores in the present study were very low and showed significant improvement despite the high potential of a floor effect. Similar reductions in depression have been observed following an acute bout of both aerobic and anaerobic exercise in individuals with low baseline depression (Chase & Hutchinson, 2015). Overall, the present study highlights small but significant reductions in depression that could be used to help regulate daily mood levels. As previous research suggests exercise interventions have significant effects on MDD (Stanton et al., 2013), it is possible these effects are due to stacking/combining the effects of individual acute bouts of exercise. Therefore, continued participation in either HIIE or MIA could lead to chronic improvements in depressive symptoms especially in those with elevated baseline levels. However, as depression was significantly reduced following SED, it is possible the simple distraction from daily life, evident in all conditions, was responsible for the temporary reduction.

It was also hypothesized that post-exercise enjoyment would be similar following both HIIE and MIA. As the psychological responses to high-intensity interval exercise remain relatively unexplored, this hypothesis was based on the limited empirical evidence examining this phenomenon. Oliveria, Slama, Deslandes, Furtado, and Santos (2013) as well as Jung, Bourne, and Little (2014) showed enjoyment to be similar between HIIE and moderate intensity exercise. While other studies have shown HIIE to be more enjoyable relative to MIA, the participants in those studies were all highly fit, which could have influenced their responses (Bartlett et al. 2011; Thum, Parsons, Whittle, & Astorino, 2017). Additionally, Heisz, Tejada, Paolucci, and Muir (2016) found that enjoyment for HIIE and MIA were similar at baseline, but enjoyment for HIIE increased with 6 weeks of training while enjoyment to MIA remained constant. As it is reasonable to assume highly fit individuals are regular exercisers and results from Heisz et al. indicate 6 weeks of planned exercise is sufficient to increase enjoyment of HIIE, exercise history could play a vital role in post HIIE enjoyment responses. The current findings support both previous literature and the present hypothesis as participants reported similar levels of enjoyment following HIIE (93.0) and MIA (98.9). Additionally, enjoyment was significantly greater following both MIA and HIIE relative to SED (74.9). Both affective valence and enjoyment have been proposed to be intensity dependent. Strong empirical data supports the notion that affective valence and enjoyment become less positive/more negative with increasingly higher exercise intensities, within the continuous exercise domain (Ekkekakis et al., 2008). The present findings, along with emerging literature, support the notion that the psychological responses to interval exercise (i.e., enjoyment) do not follow the same path as aerobic exercise.

In-task affective valence was assessed every 5 minutes during each condition. It was hypothesized that in-task affective valence would be more positive/less negative during MIA relative to HIIE. Additionally, as higher intensity exercise has been shown to significantly decrease in-task affective valence both during interval exercise (Jung et al., 2014; Oliveira et al., 2013; Saanijoki et al., 2015) and continuous exercise (Ekkekakis et al., 2008; Kilpatrick et al., 2007), affective valence during HIIE was expected to be significantly less positive relative to SED. The results of the present study support the hypothesis and add an additional component to the existing literature. First, as both the MIA and SED condition were continuous and unimodal, Feeling Scale (FS) was assessed every 5 minutes. However, as the nature of HIIE is bimodal, having a period of high-intensity exercise and a period of rest/recovery, FS measures were taken after each interval (3 min) and after each rest period (2 min). Results indicate that in-task affective valence was significantly less positive during HIIE relative to both SED and MIA when analysis was done using FS values assessed immediately after each interval, and using the average FS values assessed after rest. Due to the continuous nature of both MIA and SED, in-task affective valence was relatively constant throughout. However, in-task affective valence would increase after rest during HIIE and decrease after the exercise intervals. The constant fluctuation of in-task affective valence during HIIE could potentially explain the similar levels of enjoyment between HIIE and MIA. As in-task affective valence has been linked to exercise enjoyment (Rejeski, 1994), and as in-task affective valence recovered to some extent during rest, this could be enough to normalize enjoyment levels.

It was also hypothesized that participants would show an increase in positive affect and decrease in negative affect following completion of both exercise conditions. The results generally support this hypothesis. Increases in positive affect are reflected by increases in activated-pleasant affective states (i.e., Energy) and/or unactivated-pleasant states (i.e., Calmness). Immediately following both HIIE and MIA, Energy levels were significantly greater relative to Pre exercise. While Energy at Post40 was not different than Pre, both exercise conditions were successful in temporarily increasing this activated-pleasant affective state. The return to baseline is most likely related to the sedentary nature of the 40-minute recovery period. This is reflected in the significant decrease in Energy during SED from Pre to Post0. For the unactivated-pleasant state of Calmness, only SED showed an immediate increase. However, all conditions showed a significant increase in Calmness at Post40 relative to Pre.

Favorable changes in negative affect are reflected by decreases in activated-unpleasant affective states (i.e., Tension) and/or unactivated-unpleasant affective states (i.e., Tiredness). While no significant changes were observed following HIIE or SED, participants showed a significant decrease in Tiredness immediately following MIA (Post0). Additionally, HIIE was well tolerated as tiredness did not increase Post0. Finally, tension was significantly reduced Post40 HIIE and at all assessments following MIA and SED. While tension was not reduced at either Post0 or Post20 following HIIE, the lack of change suggests HIIE is a viable option for individuals living with PTSD. As such, it appears that an acute bout of exercise would improve or not diminish the psychological well-being of individuals living with PTSD, ultimately improving their quality of life. While many of these changes are small in nature, even a temporary reprieve from overall mood disturbances can be critical in clinical populations. These acute changes, while small, could build over time to have a much larger impact.

One limitation to the present study was the lack of commonality in which participants experienced a traumatic event. PTSD can result from exposure to numerous traumatic events, and each may impact an individual differently. In the present sample, participants identified as personally experiencing a physical assault (n=14), Unwanted or uncomfortable sexual experience (n=13), transportation accident (n=11), sexual assault (n=11), sudden, unexpected death of someone close the them (*n*=7), assault with a weapon (*n*=6), being involved in a fire or explosion (*n*=5), exposure to toxic substance (*n*=5), combat or exposure to a war-zone (*n*=4), and captivity (*n*=1) to name a few. Additionally, of the 25 participants included in the study, 22 personally experienced two or more traumatic events, 20 experienced three or more, 16 experienced four or more, and 8 participants indicated personally experiencing five or more traumatic events. As the nature of being exposed to an accident, war-zone, sexual assault, or natural disaster differ, so too may the individual characteristics of the resulting PTSD. In the future, it would be of interest to recruit a larger sample and be able to use the primary traumatic event as a within-subjects factor. This could lead to a further understanding of how individuals with different experiences respond to various modes/intensities of exercise.

Another limitation was aerobic fitness levels. As the present sample was based on volunteers, this was difficult to control for, and males had an estimated aerobic fitness that was greater than females. Specifically, males' aerobic fitness was estimated on the low side of Good, while females were on the high end of Fair [$M_{diff} \pm SE$; 15.26 ± 2.93; CI: 9.19, 21.34; $p < .001$]. This was less of a concern because when sex was examined as a between subjects' factor, no sex differences in affective valence or enjoyment were found. Additionally, the HIIE condition was, to some extent, self-selected. While participants were instructed to give "all-out effort", the intensity with which the exercises were performed was up to the discretion of the participant. Unlike treadmill or cycle high intensity training, in which the absolute speed, grade, and resistance is under the direct control of the experimenter, the HIIE protocol was not under the same control. However, as the reported RPE and HR responses were significantly greater during HIIE relative to both MIA and SED, it is reasonable to conclude that participants were working at an appropriate intensity.

Finally, as the present study was acute, changes in PTSD symptomology were not assessed. As the PCL-5 was designed to be a chronic measure of PTSD symptomology, assessing changes in PTSD immediately after a 35-min exercise or rest condition was unwarranted. In the future, it would be of interest to determine if the protocols for HIIE and MIA used in the present study have a direct effect on PTSD symptomology after a longitudinal intervention. As such, the results of the present study are limited to comorbid conditions of PTSD, and overall psychological responses to exercise in this special population.

Conclusions

Overall, the present study is the first to examine the acute psychological effects of exercise within a sample of individuals living with subsyndromal PTSD. While this line of research is novel and future studies are needed to fully understand the acute psychological effects of exercise within this population, the present study sheds light on these effects. Specifically, an acute bout of MIA, HIIE, and SED were effective in temporarily decreasing anxiety, depression, and tension, as well as increasing affective valence and calmness. Additionally, an acute bout of MIA and HIIE were effective in temporarily increasing energy, were well tolerated and enjoyed to a similar extent. Further, the anxiolytic effects of both MIA and HIIE appear to be stronger and last longer relative to SED, and both MIA and HIIE were enjoyed more relative to SED. Overall, the results point to the feasibility/acceptability of both HIIE and MIA for use by individuals living with subsyndromal PTSD. While in-task affective valence significantly decreased during HIIE relative to MIA, this effect was temporary and participants reported feeling significantly more positive after exercise relative to baseline. With current exercise literature on PTSD showing significant increases in PTSD symptomology and comorbid conditions (e.g., anxiety & depression) at one-month follow-ups, it is essential to fully understand the psychological effects of an acute bout of exercise. This could lead to future exercise interventions aimed at maximizing enjoyment and affective valence, which others have shown to be imperative to continued exercise participation.

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