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Perceptual Responses to High-Intensity Interval Training in Overweight and Sedentary Individuals

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Perceptual Responses to High-Intensity Interval Training in Overweight and Sedentary

Individuals

by

Nicholas Martinez

A thesis submitted in partial fulfillment
of the requirements for the degree of
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ABSTRACT

Contemporary aerobic exercise guidelines comprised of continuous durations and higher intensities have been shown to be effective in the prevention and treatment of risk factors associated with obesity and cardiovascular disease (CVD). However, high-intensity interval training (HIIT) has recently been examined as an advantageous protocol for producing more favorable physiological and psychological benefits in comparison to traditional continuous exercise guidelines. The dual-mode model, which examines the dose response relationship between exercise intensity and affective valence, would suggest that exercise performed well above the ventilatory threshold (VT) in the severe domain should result in negative affective valence.

Numerous investigations have confirmed the reliability of the dual-mode model's ability to predict compromised affective valence in the presence of heavy to severe exercise intensities, but only a small amount of research has examined the efficacy of the dual-mode model to predict affective valence during HIIT. However, no research to date has combined HIIT with the dual-mode model's efficacy to predict affective valence in target populations challenged by exercise adherence, such as overweight and sedentary individuals. Therefore, the purpose of this study was to examine the dual-mode model's reliability for predicting affective valence in overweight and sedentary individuals performing HIIT.

A total of 14 participants (7 male, 7 female) with a mean age of 23 ± 4 (range = 18-33) and mean BMI of 29 ± 3 (range = 25-33) completed the study. Each participant completed a ramp maximal exercise test to determine VT and peak power data, which allowed for specific exercise intensities of delta (DT) to be prescribed for experimental trials. Participants were low to moderate risk. The four experimental conditions were all matched for total work: 1) continuous at 10% DT (Continuous-Heavy – CH), 2) 24 x 30-second intervals at 60% DT (Interval-Severe 30 Second – IS30), 3) 12 x 60-second intervals at 60% DT (Interval-Severe 60 Second – IS60), 4) 6 x 120-second intervals at 60% DT (Interval-Severe 120 Second – IS120). The continuous exercise condition was 20 minutes in duration, whereas all interval exercise conditions were 24 minutes in duration.

Results indicated that in-task perceptual responses defined, as affective valence and perceived enjoyment were generally more favorable during IS30 and IS60 in comparison to CH and IS120. Affective valence was significantly greater at time-points 3 through 6 during IS30 and IS60 in comparison to CH ($p < 0.05$). Ratings of perceived enjoyment were significantly greater at all measured time points during IS60 in comparison to CH ($p < 0.05$). The findings of this study suggest that HIIT comprised of either 30 or 60 seconds facilitate more favorable perceptual responses of affective valence and perceived enjoyment than continuous exercise and intervals longer than 60 seconds duration.

CHAPTER 1: INTRODUCTION

Rationale

The obesity epidemic in the United States is believed to be an unintentional consequence of the socioeconomic and technological developments that have occurred over the past several decades (Sunyer, 2002). Recent statistics indicate that more than 66% of the American adult population is currently overweight and 32% are obese (Ogden et al., 2006). Elevated body mass index (BMI), particularly in the intra-abdominal and upper body region is associated with multiple cardiovascular and metabolic abnormalities, which increase the risk for morbidity and mortality (Sunyer, 2002). Some of the medical consequences of obesity include hypertension, hyperlipidemia, metabolic syndrome, type II diabetes mellitus, cardiovascular disease (CVD), musculoskeletal disease, and psychological disorders (Reilly et al., 2003). Contemporary aerobic exercise guidelines comprised of extended continuous durations at higher intensities have been shown to be effective in the prevention and treatment of risk factors associated with obesity (ACSM, 2010). However, adherence to physical activity programs is often compromised following exercise bouts of extended durations (Balady, 2000), while negative perceptual responses have been reported as exercise intensity increases above accustomed levels (Yeung, 1996).

Interval training has recently been examined as an advantageous protocol for producing more favorable perceptual responses (Bartlett et al., 2011; Greeley, 2012), as well as potentially being more time-efficient in comparison to traditional continuous exercise guidelines (Gibala, 2007). Low volume, high intensity interval training (HIIT) involves discontinuous exercise in which short periods of high intensity exercise are followed by periods of light recovery or rest. Traditional HIIT, such as Wingate-style cycling is comprised of four to six bouts of 30-second anaerobic sprint activity followed by four-minutes of light aerobic pedaling. Modified or ‘practical’ HIIT protocols utilize intensities relative to individual performance on VO_{2peak} tests, and include approximately one minute sprint and recovery intervals each, which aim to elicit a near-maximal heart rate upon completion of 10 total intervals (Little et al., 2010). Both traditional and modified HIIT protocols allow for favorable health and performance adaptations to occur at a fraction of the time in comparison to contemporary guidelines for continuous exercise (Gibala et al., 2006).

Recent work examining traditional HIIT protocols have shown their effectiveness for reducing cardiovascular and metabolic risk factors in sedentary, overweight and obese males. A sample from the aforementioned target population participated in a two-week HIIT study, which significantly reduced waist to hip ratios in addition to improvements in short-term systolic blood pressures (Whyte, Gill, & Cathcart, 2010). A similar study found significant improvements in systolic blood pressure and BMI for youth participants following a HIIT intervention (Buchnan et al., 2011). Babraj and colleagues (2009) found that a 2-week HIIT program was effective in improving insulin sensitivity in addition to increases in aerobic performance for sedentary males. Additional studies have suggested

that HIIT can be efficacious for older participants suffering from intermittent claudication and type II diabetes (Earnest, 2009). These findings suggest that HIIT is an effective protocol for improving CVD risk factors for a variety of youth to elderly populations.

An early traditional HIIT study conducted by Tabata and colleagues (1996) resulted in a popular interval protocol in which individuals exercise for 20 seconds at an intensity that is approximately 170% of their VO_{2peak} , followed by 10 seconds of rest. One complete Tabata session is comprised of eight cycles that total four minutes inclusive of both work and rest components. The results of this five week study comprised of extremely high intensity intervals showed that participants improved their VO_{2peak} in addition to lowering their ratio of lean body mass to fat without compromising muscle mass (Tabata et al., 1996). While traditional HIIT protocols have been shown to provide increased health benefits, they were initially developed with athletic populations in mind for performance enhancement. Participants commonly report experiencing nausea and or light-headedness following traditional HIIT (Richards et al., 2010), whereas other participants are capable of enduring the same or similar types of high intensities without tolerability issues (Whyte, Gill & Cathcart, 2010).

Practical HIIT protocols were developed in an attempt to retain the benefits and time efficacious nature of traditional HIIT, while addressing the concerns regarding tolerability (Little et al., 2010). Practical HIIT allows individuals to still incur physiological adaptations while exercising at approximately one half of the intensity of traditional HIIT. Recent studies have emphasized the potential of practical HIIT to provide favorable health benefits for sedentary and special populations. These studies suggest that practical HIIT can directly improve CVD and metabolic risk factors such as

blood glucose concentrations and insulin sensitivity respectively (Hood, Little, Tarnopolsky, Myslik & Gibala, 2011; Little et al., 2011). Despite the potential of practical HIIT to facilitate the aforementioned benefits, there still remains a concern for how non-athletic populations will respond acutely and adhere to HIIT protocols.

In examining the dose-response relationship of exercise intensities, the dual-mode model suggests that exercise intensities in the moderate domain will result in fairly homogeneous responses of affective valence, whereas higher exercise intensities in the heavy domain tend to produce heterogeneous responses of affective valence (Ekkekakis, Hall & Petruzzello, 2005). It has also been reported that exercise intensities that approach maximal effort or severe domain result in a reduction of pleasure (Ekkekakis, Hall & Petruzzello, 2008). Therefore, the dual-mode model would predict that HIIT, which is performed at intensities in the severe domain, should result in negative affective responses. It is reasonable to speculate that decreases in affective valence could in turn reduce the motivation of individuals to adhere to HIIT programs.

A study conducted by Raedeke (2007) revealed that enjoyment was linked with improvements in affective valence. However, the affective responses reported in the aforementioned study were only measured pre and post exercise, which raises the concern for whether or not affective responses may have been significantly different if measured in-task as well. In a recent study conducted by Bartlett and colleagues (2011), researchers revealed that recreationally active males had a higher rating of perceived enjoyment following HIIT in comparison to moderate-intensity continuous exercise. While the Dual-Mode model has recently been employed to investigate the perceptual

responses of recreationally active participants to HIIT (Greeley, 2012), it has yet to be applied to overweight and sedentary populations.

Purpose

The health benefits and time efficiency associated with low-volume, high intensity interval training has recently piqued the interests of researchers investigating optimal exercise protocols for at risk populations. While the literature thus far has served an important role in understanding how HIIT influences physiological variables, measurements of psychological responses for at risk populations performing HIIT could provide insight into how motivated these individuals will be to continue similar programs in the future. Importantly, the Dual-Mode Model (Ekkekakis, 2003) provides a theoretical framework for the dose-response relationship between exercise intensity and affect. However, the research examining psychological responses to HIIT is still in its infancy, and no study to date has investigated at risk and overweight populations. Therefore, the next logical step in piecing together the dynamic puzzle of how to increase exercise adherence amongst at risk and overweight individuals would be to compare the psychological responses to both continuous and discontinuous bouts of exercise in at risk populations.

Study Variables

The independent variable in this study was the exercise intervention, which is comprised of four levels. There were three sessions of interval exercise and a single session of continuous exercise. All interval sessions consisted of varying time intervals

(30sec, 60sec, 120sec) performed at a severe-intensity ($60\% \pm 5$ of delta), which were matched for both total amount of work and time with the continuous session. The single continuous session was performed at a heavy-intensity ($10\% \pm 5$ of delta). The dependent variables measured for this study were affective valence and ratings of perceived enjoyment.

Hypotheses

H₀₁: There will be no difference in perceptual responses during exercise among the various conditions.

H_{A1}: There will be a more favorable affective valence during all HIIT conditions in comparison to the heavy-intensity continuous exercise condition.

H_{A2}: There will be a higher rating of perceived enjoyment during all HIIT conditions in comparison to the heavy-intensity continuous condition.

Conceptual Model

The theoretical framework linked to the proposed project is the Dual-Mode Model, which suggest that affective responses to acute exercise are dependent upon the specified exercise intensity (Ekkekakis, 2003). The conceptual framework proposes that affective responses to exercise are characterized by an interaction between psychological processes and physiological responses. Additionally, the dual-mode model provides a representation of the dose-response relationship observed between intensity and affective valence during exercise. The transition from aerobic to anaerobic energy systems provides a physiological marker for better understanding the interplay between exercise

intensity and affective valence (Ekkekakis, 2003; Ekkekakis et al, 2005). Three specified domains of exercise intensity are to be utilized, which are known as moderate, heavy and severe (Ekkekakis et al., 2005).

Moderate intensity can be described as exercise beneath the ventilatory threshold (VT), which relies primarily upon the body's aerobic energy system to support the associated demands of slow-twitch muscle fiber activity. The affective responses to moderate intensity exercise tends to be pleasurable, with little deviation amongst participants. Ekkekakis and colleagues (2005) purport that the influence of cognitive factors facilitate the increase in positive affective valence during moderate intensity. Researchers have theorized that moderate intensity activity is adaptive and may operate via a reward mechanism that works to increase or preserve pleasure (Ekkekakis et al., 2005).

Heavy intensity can be conceptualized as physical activity that spans the lactate threshold and approaches an intensity marker known as critical power (CP) or maximum lactate steady state (MLSS). Theoretically, this intensity domain allows for a heavy work rate in which the lactate accumulation to clearance ratio can still be stabilized (Ekkekakis et al., 2005). While heavy intensity exercise can be performed for a reasonable length of time, there is a high level of inter-individual variability due to cognitive factors that contribute heavily to each individual's capacity to sustain a specified work rate. It is theorized that factors such as goal achievement, self-efficacy, and individual personality characteristics contribute to affective valence during heavy intensity physical activity.

Severe intensity corresponds with physical activity between CP and peak power. It is within this severe-intensity domain that the capacity for the body's physiological

processes to clear lactate accumulation becomes compromised and can no longer be stabilized. The body's anaerobic energy system is the primary mechanism utilized to meet the demands of severe intensity exercise and is accompanied by fast-twitch muscle fiber activity. There is an accumulation of lactate that occurs within skeletal muscle during severe intensity exercise, which serves as a marker of fatigue and prompts the exerciser to discontinue activity or risk injury. It is hypothesized that interoceptive cues (physiological responses) to exercise facilitate a reduction in affective valence during the severe intensity domain. However, Ekkekakis and colleagues (2005) purport that affect works as a preservation mechanism that regulates the capacity for an individual to work in the severe intensity domain.

Operational Definitions

Continuous exercise is defined as traditional aerobic and or endurance training in which there are no intermittent breaks within the exercise session, rather the exercise session is ongoing until the specified time of completion.

Interval exercise is defined as short periods of high-intensity activity are interspersed with periods of recovery.

Affect is defined as a general, valenced response (positive or negative) that does not require higher cortical processes to precede it.

Enjoyment is defined as a psychological state directly connected to that stimulus. It is an emotion and as such, requires a cognitive appraisal of a stimulus as having positive or negative implications for one's goals or well-being.

Ratings of perceived exertion is defined as a psychophysiological approach in which the exerciser rates on a numerical scale perceived feelings relative to exertion level. This scale can be used in addition to oxygen consumption, heart rate, and blood lactate to indicate exercise intensity.

VO_{2max} or Maximal oxygen consumption is defined as the maximum capacity of the body's physiological processes to transport and utilize oxygen during graded exercise.

VO_{2peak} or Peak oxygen consumption is defined as the highest value of oxygen consumption measured during graded exercise. VO_{2peak} applies when oxygen consumption does not readily plateau or appears limited by local muscular factors.

Ventilatory threshold (VT) is defined as the point at which pulmonary ventilation increases disproportionately with oxygen consumption during graded exercise.

Lactate Threshold is defined as the exercise intensity at which lactic acid begins to accumulate faster than physiological processes can remove it.

Body mass index (BMI) is a method used for determining human body fat based on an individual's weight divided by the square of his or her height. The resulting BMI number is compared to a standard chart to determine if the individual is of below, average, or above ideal weight relative to height.

Overweight is defined as ($BMI \geq 25-29.9 \text{ kg/m}^2$).

Obesity is defined as ($BMI \geq 30-39.9 \text{ kg/m}^2$).

Assumptions

The assumptions of this study are that participants will adhere to all instructions and requirements for maximal testing and submaximal trials. It is assumed that

participants will give the required effort during all trials and not make intentional mistakes to manipulate any aspects of the study. The final assumption is that all participants will provide honest and accurate responses to all questions during each trial.

Limitations

One significant limitation of this study will be the participant's maximal effort given during the VO_{2peak} test performed on the cycle ergometer. Maximal heart rate and ratings of perceived exertion will be recorded during each participant's VO_{2peak} test, which will help to determine whether or not each participant provided a maximal effort. A second limitation will be the use of single item indicators for affect and enjoyment. However, there is no other reasonable option for measuring in task responses. A third limitation will be the lack of familiarity participant's may have to the exercise sessions, which may result in stress or anxiety. Efforts will be made to address this concern through a familiarization period prior to the start of any experimental trials.

Delimitations

A primary delimitation of this study will be participant characteristics, which will be comprised of adults between 18 to 45 years of age. A second delimitation is that all participants will be required to have a body mass index (BMI) between 25 and 35. A third delimitation will be that participants are considered insufficiently active or sedentary according to the guidelines set forth by the American College of Sports Medicine (ACSM, 2010). Participants will need to be free from taking any prescription medications for CVD risk factors or psychological disorders. Additionally, participants

will be instructed to refrain from engaging in any new exercise programs until completion of their total number of trials. Additionally, participants will be expected to refrain from any significant physical activity during the 24 hours prior to each laboratory appointment.

Significance

Researchers have long been interested in discovering new ways to improve exercise adherence amongst sedentary, overweight and obese populations. Adherence to physical activity programs are compromised by extended bouts of exercise (Balady, 2000), in addition to exercise intensities above unhabituated domains (Yeung, 1996). HIIT has the potential to address both of the aforementioned concerns related to continuous exercise guidelines. HIIT can be more time efficient in facilitating physiological adaptations (Little et al., 2010), in addition to improvements in rating of perceived enjoyment compared to continuous modes of exercise (Bartlett et al., 2011). While there is substantial literature to support the physiological benefits associated with HIIT, measurement of specific psychological responses including affective valence and enjoyment are still in the beginning stages, and have yet to be applied to obese or at risk populations.

Measurement of enjoyment and affective responses that occur during interval and continuous modes of exercise will provide insight into understanding how specific exercise protocols might promote adherence amongst obese and sedentary individuals in the future. The proposed study will aim to utilize physiological and psychological data to determine a favorable exercise protocol that optimizes the potential for physical activity

adherence amongst obese and sedentary individuals. Examination of the study's hypotheses will provide scientific evidence as to why specific exercise protocols should be implemented into the beginning stages of periodized exercise programs for the target population, and why other protocols should be avoided. The aim of this proposed study is to build on the work of previous research and provide data that will contribute appropriately to similar areas of scientific investigation in the future.

CHAPTER 2: LITERATURE REVIEW

Obesity and Sedentary Behavior

Sedentary behavior is a primary contributor to the development of obesity, which is a primary risk factor for cardiovascular and metabolic diseases (Hu, 2003). Obesity and physical activity tend to exhibit an inverse relationship. The more weight an individual gains, the more difficult it can be for the bioenergetic and musculoskeletal systems to meet the demands of regular exercise and or standard activities of daily living.

Individuals that have a greater BMI in the upper body region are at a higher risk for fatal health complications (Sunyer, 2002). Obesity has the potential to develop into health threatening morbidities including hypertension, hyperlipidemia, metabolic syndrome, type II diabetes mellitus, cardiovascular disease (CVD), musculoskeletal issues, and psychological disorders (Reilly et al., 2003). The economic burden that obesity presents to the healthcare system as well as the decline of young adults capable of passing military physical exams has resulted in congress officially recognizing obesity as a threat to the United States national security (DeMattia & Denney, 2008; Blitekoff, 2007).

A study conducted by Finkelstein and colleagues (2009) found that obesity-related costs were as high as \$140 billion each year. It is approximated that if an individual suffers from obesity and lives a sedentary lifestyle, their health care costs are 40 percent more than that of his or her healthy average weight counterparts. According to

the 2010 publication “The Surgeon General’s Vision for a Healthy and Fit Nation”, more than 100,000 Americans die each year from preventable diseases related directly to obesity. Lack of exercise often accelerates an individual’s propensity towards obesity, which in turn increases the risk for contracting cardiovascular and metabolic diseases in addition to various cancers. The benefits associated with consistent exercise on cardiovascular disease risk factors include a reduction in blood pressure, reduction of LDL and total cholesterol, increase in insulin sensitivity, reduction in body weight, and an overall increase in exercise tolerance (Myers, 2003).

Sedentary behavior and physical activity are not mutually exclusive. Individuals can be both sedentary and physically active during a given daily routine. For example, low-active high-sedentary individuals tend to be more overweight than high-active low-sedentary individuals (Wong & Leatherdale, 2008). An individual’s total daily volume (conceptualized as the frequency, intensity, and duration of physical activity) ultimately determines where individuals reside within the continuum of low-active high-sedentary to high-active low-sedentary behaviors (Greeley, Martinez, & Campbell, 2013).

Time Barrier to Exercise Adherence

Time management is an important yet elusive concept for many Americans to comprehend, especially when it pertains to making the time to engage in regular physical activity programs. Among the numerous reasons given as barriers to exercise, Americans often cite lack of time as the primary reason for not adhering to traditional exercise programs (Troost et al., 2002). According to the physical activity guidelines set forth by the American College of Sports Medicine (ACSM, 2010), the general population should

engage in 30 minutes of moderate to vigorous aerobic exercise most days of the week. Guidelines for overweight and obese individuals suggest progressing to approximately 50 to 60 minutes of moderate to vigorous aerobic exercise 5 days a week. Additionally, some individuals may require between 60 to 90 minutes of moderate to vigorous daily exercise to facilitate or maintain weight loss. One of the major problems with these popular recommendations is that adherence to physical activity programs is negatively affected following bouts of exercise exceeding 60 minutes (Balady, 2000).

Contemporary guidelines also suggest that intermittent exercise can be implemented throughout the day to meet the recommended guidelines for physical activity (ACSM, 2010). Rather than completing a continuous bout of exercise comprised of 60 minutes, individuals can choose to perform the recommended amount of exercise in 4 to 6 intermittent sessions of 15 or 10 minutes respectively. Multiple studies have shown that intermittent exercise may be equal to or more effective than continuous exercise for improving risk factors associated with cardiovascular disease (Murphy, Nevill, Neville, Biddie, & Hardman, 2002; Donnelly, Jacobsen, Heelan, Seip & Smith, 2000; Coquart, Lermaire, Dubart, Luttembacher, Douillard & Garcin, 2008). While capable of providing similar health benefits to continuous exercise, intermittent exercise does not result in overall shorter durations. Therefore, intermittent or continuous exercise recommendations that approach or exceed 60 minutes or longer may have equal potential to negatively affect adherence to physical activity programs. Future exercise protocols that are capable of preserving perceptual responses and physiological benefits while also addressing concerns of duration and intensity would be of great interest and benefit to researchers and exercisers alike.

Interval Training

The early development of interval training can be traced back to the work of German track coach Woldemar Gerschler during the time of World War II (Carstairs, 1970). Gerschler's short distance interval training protocols aimed to train athlete's hearts in a similar way to other muscles, which resulted in the production of world champions and record setting times in the 800-meter dash. Gerschler's countryman Franz Stampfl later modified interval training for middle distance running, which eventually caught the attention of medical student Roger Bannister, who further modified the protocol to successfully break the 4 minute mile (Kruger, 2006). Physiologists and coaches all over the world took notice of the favorable adaptations that occurred as a result of interval training and begin to implement them into their periodization programs for athletes. Since the efficacy of interval training has become realized, these record-breaking protocols continue to be modified and developed to optimize the cardiovascular capabilities for athletic and general populations alike.

While interval training is by no means a new idea, it is still providing new developments in the way of health and performance benefits. Interval training is a type of discontinuous exercise that has resurfaced in recent years amongst researchers as a more time efficient method than continuous aerobic exercise for improving the aforementioned benefits (Gibala, 2007). Continuous exercise can be conceptualized as constant physical activity at submaximal intensities in which the body's physiological processes achieves a steady state, whereas discontinuous exercise consists of primarily higher intensity work rates interspersed with periods of recovery. The high intensity period of interval training is typically performed well above the anaerobic threshold, while the recovery period

usually consists of complete rest or a much lower work rate. Interval training is multifaceted and can involve different protocols that vary in total duration, number of intervals, intensities, and work to rest ratios.

Many athletes continue to routinely use interval training as part of their periodization programs, and literature supports the popular belief that high-intensity interval training can improve performance in elite athletes (Psilander, Wang, Westergren, Tonkonogi & Sahlin, 2011). Recent studies have highlighted the potential of HIIT to provide favorable health benefits for both sedentary and special populations. These studies suggest that practical protocols designed for special populations can improve CVD and metabolic risk factors (Hood, Little, Tarnopolsky, Myslik & Gibala, 2011; Little et al., 2011). Some of these modified protocols have even been shown to be efficacious for cardiovascular health in heart failure patients, individuals with coronary artery disease, and obese adults (Wisloff et al., 2007; Warburton et al., 2005; Schjerve et al., 2008). Therefore, it would appear that various interval-training protocols have the potential to benefit a wide spectrum of the overall population, from elite-level athletes to those with cardiovascular and metabolic disease.

Wingate-Style Interval Training

Developed in 1974 at the Wingate Institute located in Israel, the Wingate test is an anaerobic test, which is most often performed on a cycle ergometer and used primarily with athletic populations to measure anaerobic power and anaerobic capacity (Vandewalle, Gilbert, & Monod, 1987; Ayalon, Inbar, & Bar-Or, 1974). The test consists of a 30-second high-intensity exercise period in which participants pedal at maximal

speed against a constant force (Bar-Or, 1987). Over time, the Wingate test has undergone numerous modifications towards the development of newer style tests, but with similar measurement purposes (Tossavainen, Nummela, Paavolainen, Mero, & Rusko, 1996). Over the past decade, Wingate-style interval training has gained traction as a potentially useful approach for facilitating favorable physiological benefits with only an extremely low volume of work. Two studies in particular have demonstrated the favorable time-efficiency aspect associated with low volume, high intensity interval training in comparison to traditional endurance training (ET) (Gibala et al., 2006; Burgomaster et al., 2008).

Gibala and colleagues (2006) recruited trained participants to complete six sessions of HIIT over the course of two weeks, which paralleled performance and metabolic improvements to that of ET. While both the HIIT and ET groups showed similar increases in muscle oxidative capacity, muscle buffering capacity, and glycogen content following training, the improvements documented in the HIIT group were achieved at nearly 90% less training volume. The total training time was 2.5 hours for the HIIT group in comparison to 10.5 hours in the ET group. Burgomaster and colleagues (2008) extended the scientific work conducted in the aforementioned study by comparing physiological adaptations amongst HIIT and ET groups in recreationally active, but untrained participants. The results demonstrated that both groups had similar improvements in VO_{2peak} in addition to favorable adaptations in skeletal muscle carbohydrate and lipid metabolism. However, the weekly training volume for the ET group was approximately 10 times higher than the HIIT group.

Traditional HIIT has been shown to significantly improve performance markers such as VO_{2peak} in healthy and active samples (MacDougall et al., 1998; Rodas, Ventura, Cadefau, Cusso & Parra, 2000; Burgomaster et al., 2008). Multiple studies have demonstrated the efficacy of traditional HIIT by simply using practical measurements of performance such as time-trials following only two to six weeks (Burgomaster, Heigenhauser & Gibala, 2006; Gibala et al., 2006; Burgomaster et al., 2007; Burgomaster et al., 2008; Babraj et al., 2009; MacPherson et al., 2011). Additionally, both peak and mean power measurements have been shown to increase following HIIT (MacDougall et al., 1998; Burgomaster et al., 2006; Parra et al., 2000). While a substantial amount of HIIT research has focused on the performance markers associated with traditional HIIT, recent literature has begun to investigate its potency for improving CVD and metabolic risk factors in obese participants (Whyte et al., 2010). Specifically, recent research has demonstrated the efficacious nature of HIIT through its ability to increase insulin sensitivity in as little as six sessions (Richards et al., 2010).

In a study utilizing traditional HIIT, Trilk and colleagues (2011) found that a four week intervention improved circulatory function during submaximal exercise in sedentary, overweight/obese women. The same study conducted post-intervention exercise bouts at 50% VO_{2peak} for 20 minutes, which revealed that participant's heart rates were significantly lower and stroke volumes significantly higher in comparison to pre-intervention measurements. In another study utilizing Wingate-style interval training, both peripheral artery distensibility and endothelial function were improved over the course of six-weeks (Rakobowchuk et al., 2008). Babraj and colleagues (2009) found that a 2-week HIIT program was effective in reducing the area under the plasma glucose,

insulin and non-esterified fatty acids concentration-time curves. Participants in the aforementioned study also improved insulin sensitivity by 23% in addition to a 6% improvement in aerobic performance for sedentary males following just 250 kcal of work per week. Notably, Whyte and colleagues (2010) conducted a two-week HIIT study in which participants significantly reduced waist to hip ratios in addition to improvements in short-term systolic blood pressures.

Practical Low-Volume, High-Intensity Interval Training

Traditional HIIT protocols, such as Wingate-style intervals were initially designed for the purposes of improving performance among athletic populations. While interventions comprised of these severe intensities have produced important findings related to health and wellness, individuals have often reported sensations of nausea and or light-headedness following participation (Richards et al., 2010). These uncomfortable experiences are believed to negatively affect adherence to future exercise bouts of similar quality, which inspired researchers to investigate alternative methods for implementing HIIT. Little and colleagues (2010) developed a practical HIIT protocol with the intention of preserving the health benefits and time efficiency associated with traditional HIIT, while also addressing issues of tolerability. The practical protocol prescribed exercise intensities based on peak power generated during a VO_{2peak} test, which then required participants to perform work at approximately one half of the exercise intensity usually performed during traditional HIIT. The practical protocol is comprised of exercise intervals of 60 seconds, followed by 75 seconds of recovery for a total of 8-12 sets.

Recent studies involving sedentary and special populations have demonstrated that practical HIIT protocols have the potential to improve CVD and metabolic risk factors such as blood glucose concentrations and insulin sensitivity (Hood, Little, Tarnopolsky, Myslik & Gibala, 2011; Little et al., 2011). Hood and colleagues (2011) employed a protocol comprised of one-minute cycling intervals at 60% of peak power interspersed with a one-minute recovery for a total of ten sets, which elicited 80% of heart rate reserve (HRR) progressing to 95% of HRR upon completion of the final interval. Participants completed a total of six training sessions over the course of two weeks. The aforementioned protocol significantly improved insulin sensitivity.

Little and colleagues (2011) further modified the practical protocol for type 2 diabetes participants, which consisted of 10 exercise intervals of 60-seconds interspersed by 60-seconds of recovery designed to elicit a 90% maximal heart rate. This work:recovery ratio of 1:1 comprised of 6 total sessions resulted in reductions in glucose concentrations over the course of 2 weeks. Therefore, practical HIIT appears to be effective for inducing favorable health benefits in special populations. While the physiological benefits associated with HIIT are unequivocal, the impact these protocols may have on perceptual responses are purely speculative (Coyle, 2005; Hawley & Gibala, 2009). Therefore, it is of scientific importance to further investigate the impact HIIT may have on the perceptual responses of individuals and their ability to comply with HIIT protocols and adhere to them in the future.

Dual-Mode Model

Affective responses to exercise have received significant attention amongst researchers and practitioners in the field of exercise psychology. The long held belief within the field of exercise psychology was that the relationship between exercise intensities and affect exhibited an inverted-U curve. However, researchers have purported that the inverted-U curve theory fails to account for the inter-individual differences often found amongst participants (Ekkekakis, Hall & Petruzello, 2005). Ekkekakis and Petruzello (1999) discovered two methodological flaws often purported in the literature relating to the connection between exercise intensity and affective responses. The first argument addressed the false assumption that affective valence would represent a linear pattern from pre to post exercise, which resulted in the absence of measuring affective responses during exercise and may have obscured any dose-response relationship between intensity and affect. The second argument tackled the ambiguous classification of exercise intensity terminology such as *light*, *moderate*, and *vigorous*. These terms fail to conceptualize the inherent meanings behind the titles.

Ekkekakis (2003) proposed the dual-mode model to be utilized as the conceptual framework for investigating the dynamic relationship between exercise intensity and affective responses. The dual-mode model proposes that affective responses to exercise are characterized by a reciprocal relationship between psychological processes (e.g., exercise goals, personality) and interoceptive cues (e.g., physiological responses) (Ekkekakis, 2003). Therefore, the impact of these psychological and physiological factors on affective valence will ultimately depend on the spectrum of exercise intensities.

Recent studies have utilized further distinguished descriptions of intensity domains of exercise intensities: moderate, heavy and severe, Ekkekakis and colleagues (2005).

A study conducted by Ekkekakis and colleagues (2005) revealed that homogenous responses to specific intensities are heavily correlated to subcortical mechanisms that involve basic sensory cues (Ekkekakis 2003). As discussed, these homogeneous affective responses occur during both moderate and severe exercise intensities. Exercise performed at moderate intensities is considered to be adaptive in nature, whereas severe intensity exercise is considered maladaptive. The heterogeneous affective responses that occur during heavy exercise intensities are indicative of higher cortical processes. Exercise performed at the heavy domain of intensity is not necessarily adaptive or maladaptive (Ekkekakis et al, 2005).

Recent studies have conducted investigations regarding in-task affective responses to exercise intensities relative to the individualized VT of participants (Kilpatrick, Kraemer, Bartholomew, Acevedo, & Jarreau, 2007; Ekkekakis, Hall & Petruzzello, 2004). Ekkekakis and colleagues utilized a sample comprised of 30 healthy, young male and female participants, which showed a steady pattern of affective responses during incremental treadmill exercise protocols. The results suggested that affective valence was compromised as participants performed exercise at VT. Additional studies have investigated the differences in affective responses to exercise intensities above and below-VT. In one such study, 12 sedentary male participants were instructed to complete three 20-minute exercise trials comprised of one trial above-LT (at 4 mmol/l), one below-LT (at 2 mmol/l), and one self-selected intensity trial (Parfitt, Rose & Burgess, 2006). While lactate levels were not significantly different throughout the 20-

minute trials, 83% of the participants reported declines in affect during the above-VT condition. However, the below-VT condition exhibited a large amount of variability in affective responses with 42% remaining either unchanged or decreasing.

Rose and Parfitt (2007) conducted a study consisting of 19 sedentary female participants in which exercise intensities were personalized based on incremental lactate tests. The researchers described at-LT as the exercise intensity in which the lactate breakpoint occurred, whereas below-LT represented the exercise intensity 2 minutes prior to the increase of lactate, and above-LT comprised the exercise intensity where the second lactate breakpoint occurred. The results of the study showed that affective valence was compromised during the above-LT condition. Affective valence for both the at-LT and below-LT conditions were not significantly different from each other. A related study conducted by Lind, Ekkekakis & Vizou (2008) examined affective responses amongst 25 sedentary women over the course of two 20-minute exercise sessions. The intensities for the initial sessions were self-selected, whereas the follow up sessions were set at 10% above the initial self-selected session. Affect was not significantly different during the self-selected exercise condition (~98% VT), but continued to decline during the imposed intensity condition (~115% VT) and became significant at minute 5 and 15.

Ekkekakis, Hall and Petruzzello (2008) demonstrated that exercise intensities below VT have the potential to generate heterogeneous affective responses. The researchers examined the effect of three randomized, and counterbalanced exercise conditions (20% below-VT, at-VT and 10% above-VT) comprised of 30 healthy, active participants. The results suggested that affective valence was not compromised in the below- or at-VT conditions, while a significant decline in affect was revealed during the

above-VT condition with 80% of the sample reporting reductions in pleasure. Notably, 43% of the participants reported a decline in affective valence during the below-VT condition, whereas the dual-mode model would theorize intensities below-VT would result in primarily homogenous increases in affective valence. Additionally, a study conducted by Markowitz and Arent (2010) demonstrated that exercise intensities performed only 5% above-LT have the potential to reduce affect in both sedentary and physically active individuals in comparison to intensities 5% below-LT.

Perceptual Responses to HIIT

The majority of research investigating perceptual responses to exercise intensities has primarily focused on continuous modes of exercise. While the health and performance benefits of HIIT are well documented, not much is known regarding the perceptual responses to such exercise. In a recent study conducted Bartlett and colleagues (2011), researchers aimed to measure ratings of perceived enjoyment following sessions of HIIT and continuous running. Eight recreationally active participants performed a HIIT session (6 x 3 min at 90% VO_{2max}) interspersed with (6 x 3 min at 50% VO_{2max}). Ratings of perceived enjoyment was significantly higher following HIIT in comparison to the continuous running group (50 min at 70% VO_{2max}). The authors of the aforementioned study hypothesized that the greater enjoyment associated with HIIT may be relevant for improving exercise adherence. While the measurement of perceptual responses post exercise has great value in allowing researchers to draw conclusions for practical applications, it does not provide the a global measurement that could be addressed by in task measurements as well.

Recent research has been conducted in which measurements of affective valence and ratings of perceived enjoyment was measured in task during HIIT and continuous sessions (Greeley, 2012). A total of 10 participants completed four total exercise conditions. The two HIIT sessions were comprised of 10 x 60-second intervals at-VT (Interval-Heavy) and 10 x 60-second intervals at 20% above-VT (Interval-Severe). The two continuous sessions were performed at 20% below-VT [Continuous-Moderate] and at-VT [Continuous-Heavy]. The results indicated that enjoyment and affect was significantly greater during the Continuous-Moderate and Interval-Heavy sessions in comparison to the Continuous-Heavy. The conclusions of the study was that HIIT may help preserve affect, even when performing exercise at high intensities, such as domains above-VT.

CHAPTER 3: METHODS

Participants

There were a total of 15 participants recruited for this study. One participant was removed from the study due to medical concerns. Fourteen (7 male, 7 female) participants completed the study. Participants had a mean age in years of 23 ± 4 (range = 18-33). The mean BMI for participants was 29 ± 3 (range = 25-33). The mean VO_{2peak} data collected during maximal exercise testing was 27 ± 6 (range = 18.3-40.2). Thirteen out of 14 participants attained an RPE of nine or above during the maximal exercise test (mean = 9.9, range = 9-10). Thirteen out of 14 participants reached 90% of age-predicted maximum heart rate (mean = 189, range = 176-202). The mean VT for participants was identified at 44% of VO_{2peak} . Mean peak power output was $199 \text{ W} \pm 46$ (range = 140-270).

Participants had a mean workload of $50 \pm 4\%$ of peak power (range = 45-55%) during the Continuous-Heavy condition. The mean workload for all Interval-Severe conditions was $78 \pm 3\%$ of peak power (range = 75-84%). Participants had a mean delta of 109 ± 32 (range = 73-170). All participants were low-to-moderate-risk and displayed no signs or symptoms of cardiovascular, pulmonary, metabolic, or musculoskeletal disease that would compromise safety during participation in the study. All participants were students at the University of South Florida. Each participant underwent a medical

screening and health risk assessment, which was conducted by a physician at the Health and Exercise Science Laboratory prior to participation in maximal exercise testing or experimental trials. Participants received monetary compensation for their participation. Participant characteristics with means, standard deviations and ranges are shown in Table 3.1.

TABLE 3.1. Participant Characteristics

	Mean \pm SD	Range
Age (y)	23 \pm 4	18-33
Height (cm)	171 \pm 10	155-191
Weight (lbs)	186 \pm 31	133-235
BMI	29 \pm 3	25-33
VO ₂ peak	27 \pm 6	18-40
Delta	109 \pm 32	73 \pm 170

Instruments

Ratings of perceived enjoyment following experimental trials was measured using the 18-item Physical Activity Enjoyment Scale validated by Kendzierski and DeCarlo (1991). Each item is rated on a 7-point bipolar scale. Each item of the scale ranges from 1 to 7. Some items are reverse-scored. A representation of this scale can be found in Appendix A.

Affective valence during experimental conditions was measured utilizing the single-item, 11-point Feeling Scale (FS) (Hardy and Rejeski, 1989). The scale ranges from -5 to +5. Anchors are provided at 0 (Neutral) and again at all odd integers, ranging from “Very Bad” at -5 to “Very Good” at +5. The FS allows the measurement of affective valence from a dimensional perspective. This single-item measure presents a minimal burden for participants to respond while exercising. A representation of this scale is located in Appendix B.

Ratings of perceived exertion during maximal exercise tests and experimental conditions was measured via the single-item, 11-point CR-10 scale (Borg, 1998). The scale ranges from 0 to 10. Anchors range from “Rest” to “Maximal” and are given at every integer except 6, 8, and 9. A representation of this scale is located in Appendix C.

Ratings of perceived enjoyment during experimental conditions was measured by the single-item, 7-point Exercise Enjoyment Scale (EES) (Stanley, Williams & Cummings, 2009). The scale ranges from 1 to 7. Anchors are given at every integer, ranging from “Not at all” at 1 to “Extremely” at 7. This single-item measure presents a minimal burden for participants to respond while exercising. A representation of this scale is located in Appendix D.

Equipment

All maximal exercise tests and experimental conditions were performed on an electronically-braked Lode cycle ergometer (Groningen, The Netherlands). All testing and experimental trials took place in the Health and Exercise Science Laboratory at the University of South Florida, which allowed for environmental conditions to be controlled

for all participants. Blood lipids and glucose were analyzed using a Cholestech LDX System (Waltham, MA). Heart rate was monitored using a Polar heart rate monitor (Lake Success, NY). Expired gases from metabolic testing was collected and analyzed using the Vacumed metabolic cart and TurboFit 5.11 software (Ventura, CA). Height and weight of the participants was measured to the nearest 0.5 inch and 0.5 pound, respectively, on the Health' O Meter Professional scale. All data was collected and stored on an Apple iPad2 in addition to a MacBook Pro (Cupertino, CA). Statistical analysis of the data was performed using SPSS 21 (Armonk, New York).

Procedures

This study employed a within-subject experimental design and participants were randomized into controlled conditions. Participants were required to complete six visits in total. All visits were held in the Health and Exercise Science Laboratory at the University of South Florida campus located in Tampa, Florida. Participants were required to refrain from ingesting food, caffeine, and alcohol for a minimum of three hours prior to their trials. Participants were also required to refrain from engaging in vigorous exercise for the 24hrs prior to each session. Participants were instructed to mute cell phone ringers prior to the start of each session. Additionally, participants were required to be in good general health at each visit, free from any illness that may compromise their efforts during the experiment. A physician performed all medical screenings prior to any exercise trials.

First visit. Participants were greeted and directed to the lab's seated area where they were asked to complete an informed consent document. Participants were then

provided an opportunity to ask questions regarding their participation in the study. Participants were instructed to complete a health history form, which was presented to a qualified health professional to review for potential signs and or symptoms of cardiovascular, pulmonary, metabolic, and musculoskeletal disease. Height and weight were measured and recorded for each individual. A trained member of the study staff conducted a lipid and glucose assessment by way of a finger stick for each participant.

Lipid and glucose values were analyzed by a qualified health professional to determine CVD risk factors. Participants were required to adhere to standard health screening protocols and answer questions including, but not limited to age, family history, blood pressure, cholesterol, blood glucose, BMI, health habits, and recent levels of physical activity. The physician completed a physical exam form, which provided participants' clearance to safely take part in the study. All collected data was securely stored and locked inside the office of the Health and Exercise Science Laboratory at the University of South Florida Tampa, Florida.

Participants received a form with pre-exercise instructions for the current day in addition to guidelines and expectations for future visits, which were also emailed the day before with an appointment reminder. Each participant was directed to a partitioned area of the lab where they were provided with a heart rate monitor and an iPad2 containing descriptions and examples of all of the measures to be used throughout the study. This served as a manipulation check and allowed participants to ask questions regarding any of the items to ensure their understanding of the measures used in the study. Upon completion of the manipulation check, baseline heart rate and blood pressure were recorded after being seated for five minutes. The participants were then directed to the

exercise area to complete a ramp-style VO_{2peak} test on the cycle ergometer in the presence of trained members of the study staff in addition to the medical doctor. Prior to the start of the test, each participant was familiarized with the cycle ergometer and seat was height adjusted to allow for a 5-15 degree bend at the knee. Any adjustments made on the cycle ergometer were documented within each participant's file to be used in future trials.

The expectations for maximal exercise testing were verbally communicated and explained to each participant in detail. Each protocol for the maximal exercise test was individualized according to standardized formula for sedentary men and women (Wasserman, Hansen, Sue, Casaburi & Whipp, 1999). Each test began with a three-minute warm up ranging between 15 and 25 watts. After the warm was completed, the wattage increased automatically by increments of one watt every two, three or four seconds. Both heart rate and RPE were monitored continuously and recorded every minute throughout the test to ensure safety of each participant's progression throughout subsequent workloads. Blood pressure data was collected at specified work stages. The VO_{2peak} test terminated once each participant reached volitional fatigue and was no longer able to sustain a pedal cadence of 50 rpm. Upon termination of the test, the workload was adjusted back down to the same wattage as the warm-up, which allowed for continued movement of the lower extremities and ensured proper circulation and continued safety of participants. Each participant was instructed to continue the cool-down period for three minutes.

Blood pressure was taken during the recovery period to ensure the participant's safety. Participants were provided with water and a towel and encouraged to continue the cool down process for as long as they desired following termination of the test. Once

each participant dismounted the cycle ergometer, they were directed to sit quietly for 10-minutes before a final heart rate and blood pressure was recorded. Participants were then informed of their completion of their first session once all final measurements were collected and heart rate monitor was returned back to a member of the study staff. Expired O₂ and CO₂ concentrations were analyzed using a TurboFit 5.11 software and Vacumed metabolic cart (Ventura, CA). Peak power was identified as the maximal wattage completed when volitional fatigue occurred. VO_{2peak} was identified as the largest amount of oxygen consumed per minute during the test. VT was identified by visual inspection using the TurboFit 5.11 software. The analyzed data was used to prescribe exercise intensities for future experimental trials.

Second Visit. Participants returned for a familiarization session to perform a mock trial at the prescribed exercise intensity to be performed during Heavy-Continuous trial and Interval Severe trials. Each participant was greeted and directed to a seated area where they were provided with a heart rate monitor. Instructions were provided regarding the familiarization period, which was conducted on the cycle ergometer. The familiarization session was comprised of approximately five minutes of mock trials for all conditions to be performed in subsequent sessions. The exercise intensities during the familiarization sessions were at a percentage of the difference between where VT occurred and the peak power achieved during the VO_{2peak} testing. This percentage of difference between VT and peak power was defined as Delta. The halfway point of Delta is estimated to be critical power (CP), which can also be conceptualized as a secondary VT that represents the border between heavy and severe. Exercise performed below-VT is described as moderate-intensity, whereas exercise performed above VT and up to CP is

described as heavy-intensity, and exercise performed above CP and up and through peak power is described as severe-intensity.

Participants were instructed to perform a continuous bout of exercise at 10% delta, which falls within the heavy domain. Completion of the familiarization trials ensured the accuracy of the study staff's identification of VT. Adjustments could have been made during the familiarization session if necessary to further identify the capacity of each individual and ensure adherence and completion of future experimental trials. However, further manipulation was not necessary. Participants were then informed of their completion of their second visit once all final measurements were collected and heart rate monitor was returned back to a member of the study staff.

Visits three through six. The final four visits were comprised of the experimental trials. The conditions were counterbalanced using a balanced latin square to control for carry over and order effects. Each participant completed three sessions of interval exercise and one session of continuous exercise. All interval sessions were comprised of 24 minutes in duration and consisted of exercise performed at the severe-intensity domain (60% Delta), interspersed with a recovery period ranging between 10-20% of peak power. The variability of recovery intensity across the interval sessions allowed for the total amount of work to be equal for all sessions. The total amount of work was described as total MET minutes. Each 24-minute session was preceded by a two-minute warm-up and followed by a two-minute cool-down, which translates to 28 total minutes on the cycle ergometer. The first two minutes of warm-up was set at 1/3 of the participant's peak power. The final two minutes of cool-down was also set at 1/3 of the participant's peak power.

The Interval Severe 30-Second session (IS30) was comprised of twenty-four 30-second intervals interspersed with twenty-four 30-second recovery intervals. The Interval Severe 60-Second session (IS60) was comprised of 12 60-second intervals interspersed with 12 60-second recovery intervals. The Interval Severe 120-Second session (IS120) was comprised of six 120-second intervals interspersed with six 120-second recovery intervals. The Heavy-Continuous session (CH) was 20 minutes in duration and performed at the Heavy-intensity domain (10% DT). The Continuous Session also had a two-minute warm-up set at 1/3 of the participant's peak power. The 2-minute cool-down was comprised of the first minute at 2/3 of participant's peak power, and the second minute at 1/3 of participant's peak power. Participants were instructed to maintain a pedal cadence above 50 RPM during all conditions. Failure to maintain the required pedal cadence prompted a member of the study staff to inform the participant to increase their speed. Each participant successfully completed each exercise condition.

Pre-exercise. At the beginning of each experimental trial, participants were greeted and directed to the partitioned area of the lab to record baseline affect, heart rate, and blood pressure. A member of the study staff explained the exercise session to follow in full detail to the participant in addition to a review of the stems for affect, enjoyment, and exertion. The participant was then instructed to complete a pre-exercise survey on the iPad 2, which recorded the participant's FS, and perception of how hard in terms of RPE the participant believed the exercise session to follow would be. The participant was then directed to the cycle ergometer where they were prompted to begin the exercise trial.

During exercise. Heart rate was continuously monitored and recorded during the first and second minute of the warm-up and cool-down, as well during in-task perceptual

measurements. During all experimental conditions, affect, enjoyment and exertion were recorded at a percentage of completion (1/6, 2/6, 3/6, 4/6, 5/6, 6/6).

Post-exercise. Following the cool-down for each trial, each participant was directed to the partitioned area of the lab to be seated and then instructed to complete a Post-0 exercise survey on the iPad 2. The survey recorded the participant's current affect, how hard in terms of exertion the participant perceived the exercise session to be, and the participant's perceived enjoyment of the session via the 18-item PACES. A member of the study staff collected the Post-0 survey once the participant finished. Ten minutes following the exercise session the participant completed a Post-10 survey comprised of the same scales and questions asked in the Post-0 survey. Once completed, a final heart rate and blood pressure was recorded. Participants were compensated following the completion of each experimental trial.

Statistical Analyses

Data was analyzed using the Statistical Package for the Social Sciences (SPSS) 21. The criterion for significance was set at ($p < 0.05$). A descriptive analysis of the sample was completed. A repeated measures analysis of variance (ANOVA) was performed to determine whether there were any differences in affect or enjoyment among the four experimental conditions. Follow-up of paired sample t-tests were performed to identify where specific differences occurred for the experimental conditions. Effect sizes were also calculated to estimate the magnitude of specific relationships.

CHAPTER 4: RESULTS

Heart Rate and Ratings of Perceived Exertion

A descriptive analysis of heart rate and RPE was performed as a manipulation check to ensure exercise intensities were accurately prescribed, as well as to assure the safety of participants. As expected, there was a general increase in heart rate at each subsequent measured work stage for all the experimental conditions. Heart rate was typically lowest at the beginning of each exercise trial (1/6) and highest at the final measured time point (6/6) for all trials. At each manipulation checkpoint, IS30 appeared to have the lowest heart rate, IS120 the highest, and IS60 and CH were similar and fell within IS30 and IS120. The mean ratings standard deviations for heart rate at baseline, in-task, and post experimental conditions are depicted in Table 4.1. RPE increased from the beginning to the middle of exercise, but then plateaued and appeared to be sustained until the end of exercise for all conditions. Both the IS30 and IS60 had lower and similar RPE than all other conditions. IS120 had the highest RPE and appeared to be the most demanding, while CH had a range that was approximately between all other conditions. The mean ratings and standard deviations for RPE at baseline, in-task, and post experimental conditions are depicted in Table 4.2.

TABLE 4.1. Mean Ratings for Heart Rate with Standard Deviations

	CH	IS30 sec	IS60 sec	IS120 sec
Pre	80 ± 10	82 ± 10	81 ± 9	83 ± 11
Exercise 1	141 ± 14	137 ± 20	140 ± 22	151 ± 21
Exercise 2	153 ± 16	141 ± 19	156 ± 19	167 ± 14
Exercise 3	157 ± 17	144 ± 18	162 ± 17	172 ± 12
Exercise 4	162 ± 17	145 ± 18	164 ± 17	176 ± 12
Exercise 5	164 ± 17	148 ± 20	164 ± 16	177 ± 11
Exercise 6	167 ± 17	149 ± 18	168 ± 14	180 ± 10
Post	94 ± 9	88 ± 12	95 ± 9	100 ± 11

TABLE 4.2. Mean Ratings for RPE with Standard Deviations

	CH	IS30 sec	IS60 sec	IS120 sec
Pre	5 ± 2	5 ± 2	5 ± 2	6 ± 2
Exercise 1	3 ± 1	3 ± 2	4 ± 2	4 ± 2
Exercise 2	4 ± 1	4 ± 1	4 ± 2	5 ± 2
Exercise 3	4 ± 1	4 ± 2	5 ± 2	6 ± 2
Exercise 4	5 ± 1	5 ± 2	5 ± 2	6 ± 2
Exercise 5	6 ± 1	5 ± 2	5 ± 2	7 ± 2
Exercise 6	6 ± 2	5 ± 2	5 ± 3	7 ± 2
Post-0	5 ± 2	4 ± 2	5 ± 2	7 ± 3
Post-10	5 ± 2	4 ± 2	5 ± 2	7 ± 3

Affective Valence

Affective valence among conditions. Analysis of the data revealed no significant differences among conditions for baseline measurements at Pre1 or Pre2. There were no significant differences during in-task measurements at time-points 1 and 2 for any of the experimental conditions. In-task affect was significantly greater at time-points 3, 4, 5 and 6 during the IS30 in comparison to both the CH and IS120 ($p < 0.05$). IS30 was not significantly different than CH at time-point 1 ($p > 0.05$, $ES = 0.17$) or time-point 2 ($p > 0.05$, $ES = 0.30$). IS30 was not significantly different than IS120 at time-point 1 ($p > 0.05$, $ES = 0.32$) or time-point 2 ($p > 0.05$, $ES = 0.42$). In-task affect was significantly greater at time-points 3, 4, 5 and 6 during the IS60 than both the CH and IS120 ($p < 0.05$). IS60 was not significantly different than CH at time-point 1 ($p > 0.05$, $ES = 0.35$) or time-point 2 ($p > 0.05$, $ES = 0.40$). IS60 was not significantly different than IS120 at time-point 1 ($p > 0.05$, $ES = 0.50$) or time-point 2 ($p > 0.05$, $ES = 0.52$).

Additionally, in-task affect was significantly greater at time point 5 during the IS30 in comparison to the IS60 ($p < 0.05$). Neither the CH nor IS120 were significantly greater than any other conditions during in-task measurement at any of the measured time points. Post-0 affect was significantly greater following the IS60 in comparison to IS120 ($p < 0.05$). Post-10 affect was also significantly greater following the IS60 in comparison to CH ($p < 0.05$). The mean ratings and standard deviations for affective valence at baseline, in-task, and post experimental conditions are depicted in Table 4.3.

Affective valence within conditions. The absence of significant differences at baseline allowed for an analysis of affective valence within specific conditions. While in-task affect declined during all four experimental conditions from time-points 1 to 6, not

all decreases were significant. There was a significant decrease 3.2 ± 1.3 to 0.7 ± 2.7 (decline = 2.5) during the CH ($p < 0.05$, ES = 1.25). Similarly, in-task affect also decreased significantly 3.0 ± 1.4 to 0.9 ± 2.8 (decline = 2.1) during the IS120 ($p < 0.05$, ES = 1.00). Additionally, there was a significant decline 3.6 ± 1.0 to 2.6 ± 1.5 (decline = 1.0) during IS60 ($p < 0.05$, ES = 0.80). A decline for in-task affect was observed during the IS30 3.4 ± 1.1 to 2.9 ± 1.4 (decline = 0.5), but did not reach statistical significance ($p > 0.05$, ES = 0.40). Therefore, it appears as though the IS30 preserved affect to a greater degree in comparison to all other experimental conditions. Additionally, there were no significant differences between Pre1 and Post-10 within any of the conditions following exercise ($p > 0.05$). While in-task affect declined to some degree during all conditions, Post-10 affect returned back to baseline Pre1 values following exercise. The decline in affective valence for experimental conditions are depicted in Figure 4.1.

Affective valence hypotheses. H_{A1} stated that there would be a more favorable affective valence during all HIIT conditions in comparison to the continuous exercise condition. While in-task affect was significantly greater during both the IS30 and IS60 in comparison to CH at the majority of measured time points, IS120 was not significantly greater than CH at any of the measured time-points. Therefore, the decision is to reject H_{A1} .

TABLE 4.3. Mean Ratings for Affect with Standard Deviations

	CH	IS30	IS60	IS120
Pre1	3.7 ± 1.3	3.5 ± 1.2	3.4 ± 1.3	4.0 ± 1.0
Pre2	3.7 ± 1.3	3.3 ± 1.5	3.4 ± 1.3	3.9 ± 1.0
Exercise 1	3.2 ± 1.3	3.4 ± 1.1	3.6 ± 1.0	3.0 ± 1.4
Exercise 2	2.6 ± 1.5	3.0 ± 1.2	3.1 ± 1.0	2.3 ± 2.1
Exercise 3	1.9 ± 1.9	3.0 ± 1.3*^	2.9 ± 1.3*^	1.9 ± 2.0
Exercise 4	1.6 ± 2.1	2.8 ± 1.6*^	2.6 ± 1.3*^	1.6 ± 2.5
Exercise 5	1.0 ± 2.8	2.9 ± 1.5*^#	2.4 ± 1.3*^	0.9 ± 2.9
Exercise 6	0.7 ± 2.7	2.9 ± 1.4*^	2.6 ± 1.5*^	0.9 ± 2.8
Post-0	2.9 ± 2.1	3.2 ± 1.6	3.8 ± 0.8^	2.7 ± 1.7
Post-10	3.1 ± 1.4	3.6 ± 1.4	3.9 ± 0.8*	3.4 ± 1.5

* denotes significantly different from Continuous-Heavy

^ denotes significantly different from Interval-Severe 120 sec

denotes significantly different from Interval-Severe 60 sec

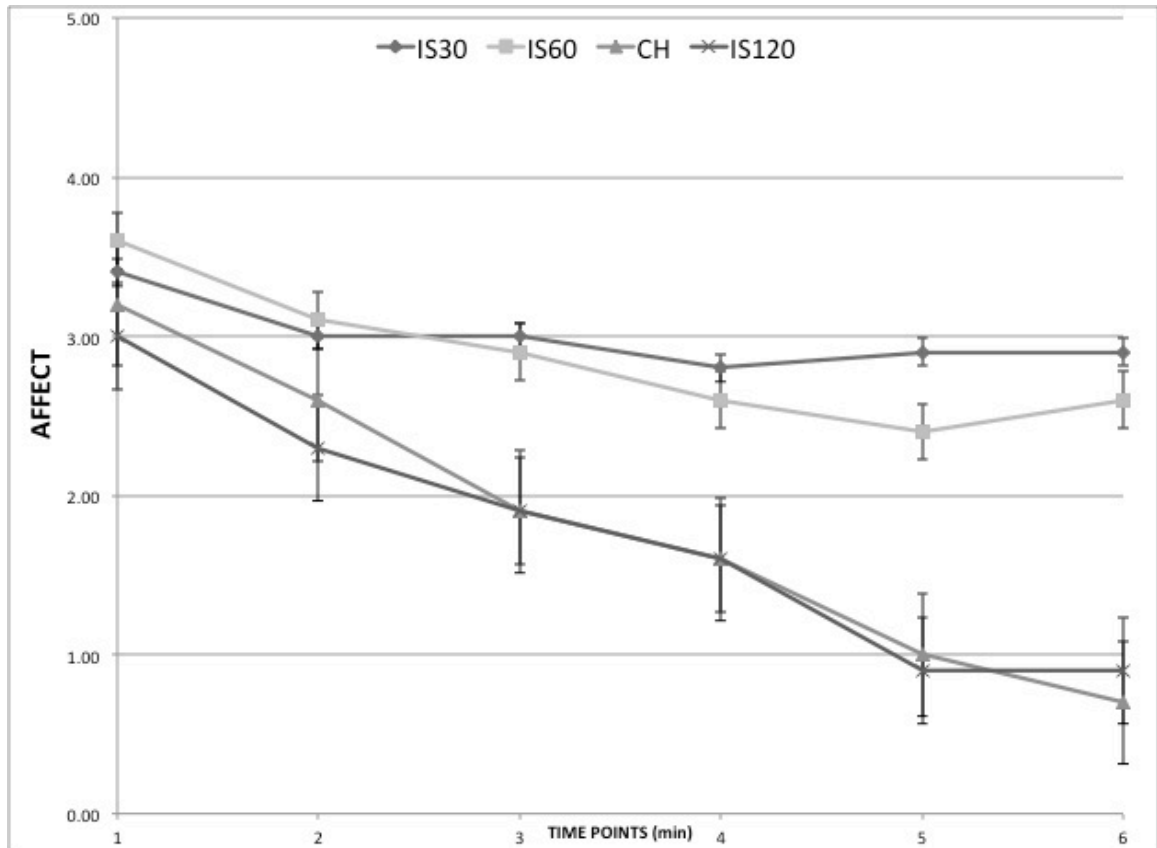


FIGURE 4.1. Decline in Affective Valence Within Conditions. All conditions declined significantly except for IS30.

Enjoyment

Enjoyment among conditions. In-task enjoyment was significantly greater at all time-points during IS60 in comparison to CH ($p < 0.05$). IS60 was significantly greater at time-points 2, 3, 4 and 5 in comparison to IS120 ($p < 0.05$). IS60 was greater at time point 1 in comparison to IS120, but not significantly ($p > 0.05$, $ES = 0.34$). IS60 was greater at time point 6 in comparison to IS120, but not significantly ($p > 0.05$, $ES = 0.38$). In-task enjoyment for IS30 was significantly greater at time points 1, 3, 4, 5 and 6 in comparison to CH ($p < 0.05$). IS30 was greater at time point 2 in comparison to CH, but did not reach significance ($p > 0.05$, $ES = 0.43$). Additionally, IS30 was significantly

greater at time points 4, 5 and 6 in comparison to IS120 ($p < 0.05$). IS30 was greater than IS120 at the beginning of exercise, but not significantly different at time-points 1 ($p > 0.05$, ES = 0.31), 2 ($p > 0.05$, ES = 0.15) and 3 ($p > 0.05$, ES = 0.36). Neither CH nor IS120 were significantly greater than any other condition during at any of the time points in which data was collected ($p > 0.05$). Post-0 enjoyment was significantly greater following IS60 than CH and IS120 ($p < 0.05$). Similarly, Post-10 enjoyment was significantly greater following IS60 ($p < 0.05$) in comparison to CH, IS120, as well as IS30. The mean ratings and standard deviations for enjoyment at baseline, in-task, and post experimental conditions are depicted in Table 4.4.

Enjoyment within conditions. A decline for in-task enjoyment was observed during all experimental conditions, but was not significant for all conditions. A decline for in-task enjoyment was observed during CH 3.2 ± 1.1 to 2.7 ± 1.6 (decline = 0.5), but did not reach significance ($p > 0.05$, ES = 0.36). IS120 declined 3.6 ± 1.5 to 2.9 ± 1.9 (decline = 0.7), but not significantly ($p > 0.05$, ES = 0.41). IS30 declined 4.0 ± 1.1 to 3.6 ± 1.5 (decline = 0.4), but was not significant ($p > 0.05$, ES = 0.30). However, there was a significant decrease 4.1 ± 1.4 to 3.5 ± 1.3 (decline = 0.6) during IS60 ($p < 0.05$, ES = 0.43). Notably, there was no significant difference in enjoyment from Post-0 to Post-10 following data analysis of within experimental conditions ($p > 0.05$). The decline in enjoyment for experimental conditions are depicted in Figure 4.2.

Enjoyment hypothesis. H_{A2} stated there would be a higher rating of perceived enjoyment during all HIIT conditions in comparison to CH. While in-task enjoyment was significantly greater at multiple time-points during both IS30 and IS60 in comparison to

the CH, IS120 was not significantly greater than CH. Therefore, the decision was to reject H_{A2} .

TABLE 4.4. Mean Ratings for Enjoyment with Standard Deviations

	CH	IS30	IS60	IS120
Exercise 1	3.2 ± 1.1	4.0 ± 1.1*	4.1 ± 1.4*	3.6 ± 1.5
Exercise 2	3.1 ± 1.4	3.7 ± 1.3	4.0 ± 1.3*^	3.5 ± 1.4
Exercise 3	3.0 ± 1.5	3.7 ± 1.3*	3.9 ± 1.5*^	3.2 ± 1.5
Exercise 4	2.9 ± 1.2	3.8 ± 1.8*^	3.8 ± 1.4*^	3.0 ± 1.6
Exercise 5	2.8 ± 1.5	3.9 ± 1.6*^	3.6 ± 1.5*^	3.0 ± 1.6
Exercise 6	2.7 ± 1.6	3.6 ± 1.5*^	3.5 ± 1.3*	2.9 ± 1.9
Post-0	81 ± 23	92 ± 15	98 ± 13*^	81 ± 25
Post-10	81 ± 22	91 ± 17	101 ± 14*^#	84 ± 24

* denotes significantly different from Continuous-Heavy
 ^ denotes significantly different from Interval-Severe 120 sec
 # denotes significantly different from Interval-Severe 30 sec
All in-tasks measurements were recorded via single item EES
All post measurements were recorded via 18- item PACES

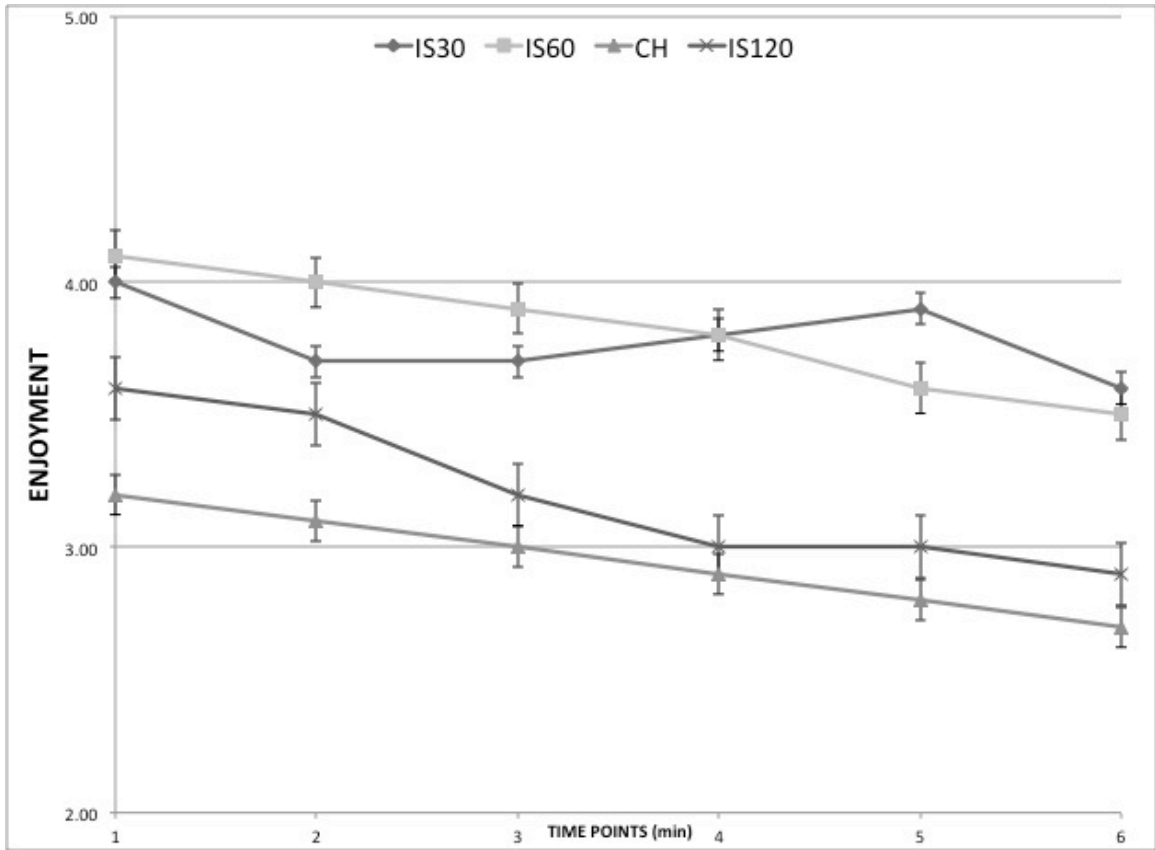


FIGURE 4.2. Decline in Enjoyment Within Conditions. IS60 was the only condition that declined significantly.

CHAPTER 5: DISCUSSION

Recent studies have highlighted the potential of high-intensity interval training to provide favorable health benefits for sedentary, overweight and special populations (Hood, Little, Tarnopolsky, Myslik & Gibala, 2011; Little et al., 2011; Whyte, Gill, & Cathcart, 2010). Additionally, interval training has been examined as an advantageous protocol for producing more favorable perceptual responses (Bartlett et al., 2011; Greeley, 2012), as well as potentially being more time-efficient in comparison to traditional heavy continuous exercise guidelines (Gibala, 2007). However, no study to date has examined the perceptual responses to interval training in overweight and sedentary individuals. This study examined the aforementioned target population and their perceptual responses to exercise by way of comparing HIIT against traditional continuous exercise on a cycle ergometer. The purpose of this study was to utilize physiological and psychological data to determine a favorable exercise prescription that could optimize the potential for physical activity adherence amongst overweight and physically inactive individuals.

This study utilized the conceptual framework of the dual-mode model to examine whether or not heavy and severe exercise intensities performed by way of continuous and HIIT respectively; support the model's theory. The intensities prescribed during this study reflected the heavy and severe domains found within the dual-mode model, which

represents the dose-response relationship observed between intensity and affective valence during exercise. The hypotheses of this study stated that the perceptual responses during severe exercise intensities encountered during HIIT would be perceived more favorably than heavy intensities encountered during continuous exercise. The findings of this study provide evidence that suggests a need to reexamine the contemporary theories regarding perceptual responses to exercise performed at severe intensities encountered during various exercise modes such as HIIT.

Affect

In-task affect. The dual-mode model hypothesizes that exercise performed above VT will compromise affective valence. It has been postulated that exercising at unaccustomed high intensities has the potential to negatively affect future adherence to exercise programs, since individuals tend to engage in activities that provide pleasure and avoid those that result in displeasure (Ekkekakis, 2003). The dual-mode model states that intensities within the heavy domain ranging between VT and CP will introduce variability in perceptual responses (pleasure or displeasure) due to the strong influence of cognitive factors (e.g., expected outcomes of exercise) (Ekkekakis, Hall & Petruzzello, 2005). The model further states that exercise performed at intensities within the severe domain between CP and peak power will result in homogeneity of perceptual responses (displeasure) due to the strong influence of physiological cues (e.g., increases in muscle pH) (Ekkekakis, Hall & Petruzzello, 2008).

A relevant finding of this study is that in-task affect was greater at the majority of time points (3, 4, 5, and 6) during 30 and 60-second intervals in comparison to

continuous exercise. In-task affect was also greater for time points 1 and 2 during 30 and 60-second intervals in comparison to continuous exercise, but did not reach significance. Therefore, it appears that participants found the aforementioned HIIT prescriptions to be a more favorable mode of physical activity than continuous exercise. The lack of significance during the early part of HIIT in comparison to continuous exercise could be due to either a lack of statistical power, or simply that the early part of exercise facilitated similar metabolic demands for all conditions equally. These findings build upon recent novel research, which showed that severe intensity intervals approached significance at numerous time-points in comparison to continuous heavy exercise (Greeley, 2012).

A lower RPE was also observed during both 30 and 60-second intervals in comparison to continuous exercise. This observation supports previous findings, which suggests that sedentary individuals prefer intermittent exercise, rather than continuous exercise at a fixed intensity since it is perceived to be easier as indicated by lower RPE (Coquart et al., 2008). The interspersed periods of severe intensity followed by active-light recovery encountered during 30 to 60-second bouts of interval training appears to preserve affective valence to a greater degree in overweight and sedentary individuals than heavy intensity continuous exercise. This study's findings regarding optimal HIIT prescriptions for overweight and sedentary individuals both supports and adds to previous scientific investigations, which aimed to develop a practical HIIT prescription comprised of 10 exercise intervals for 60-seconds interspersed by 60-seconds at 90% maximal heart rate, which has the potential to improve CVD and metabolic risk factors (Hood, Little, Tarnopolsky, Myslik & Gibala, 2011; Little et al., 2011), while also considering tolerability to HIIT (Little et al., 2010).

It is important to remember that all conditions were matched for total work, which required an equal amount of energy expenditure during each exercise session. However, the 120-second interval had unfavorable affective responses in comparison to the 30 and 60-second trials. Therefore, it appears there may be factor for time in which severe interval exercise can be tolerated before affective valence is compromised. The findings of this study suggest the threshold in which severe exercise intensities can be sustained without compromising affect valence resides between 30 and 60 seconds. Severe intervals above 60 seconds or heavy continuous exercise may facilitate a decline in affective valence. Therefore, while interval training at severe intensities appears to facilitate more favorable affective responses in comparison to heavy continuous exercise, consideration of shorter interval durations below 120 seconds may be critical when designing exercise prescriptions for overweight and sedentary individuals, as it has been suggested that exercising at unaccustomed severe intensities has the potential to compromise future adherence to exercise programs (Ekkekakis, 2003; Yeung, 1996).

A decline for in-task affect was observed throughout all experimental conditions. However, the 30-second interval was the only experimental condition that did not decline significantly. Therefore, it appears as though the 30-second interval may have the potential to preserve affect to a greater degree than all the other exercise conditions in this study. Additionally, a lower mean heart rate was observed during the 30-second interval in comparison to all other experimental conditions. This physiological observation suggests that 30-second intervals are not as demanding on the cardiovascular system as longer duration intervals. This is not to suggest that 30-second intervals are inferior to longer duration intervals in regards to facilitating physiological adaptations.

The findings of this study would suggest that severe intensity intervals comprised of both 30 and 60 seconds should be considered as an optimal prescription for facilitating physiological adaptations while also preserving affective valence. These findings support recent research, which suggests that HIIT may facilitate a preservation of in-task affective valence when performing exercise at intensities above VT (Greeley, 2012). Consideration of exercise prescriptions that aim to preserve in-task affective valence are relevant; as recent studies have suggested that favorable affective valence has the potential to predict future physical activity participation in sedentary individuals (Williams et. al., 2008; Williams, Dunsiger, Jennings & Marcus, 2012).

Post-exercise affect. Previous findings have suggested that exercise bouts typically result in an increase in post-exercise affect back to baseline values or even higher (Parfitt, Rose & Burgess, 2006; Ekkekakis, Hall & Petruzello, 2008). The findings in this study supports this postulation as there were no significant differences observed between Pre1 and Post-10 affect following exercise for any of the experimental conditions. Although in-task affect declined significantly for 60 and 120-second intervals as well as the continuous bout, it appears that post-exercise affect was not significantly compromised by the prescribed exercise stimulus and eventually rebounded close to baseline values. This study's findings are in opposition to Markowitz & Arent (2010), which suggested 20 minutes of exercise at 5% above the lactate threshold required 30 minutes of recovery for affect to rebound to baseline values. However, it is important to consider that previous findings have suggested that it is not post-exercise affective valence, but rather in-task affective valence that accurately predicts future adherence to physical activity programs (Williams, Dunsiger, Jennings & Marcus, 2012).

In this current study, participants performing 30 and 60-second intervals at severe intensities, which is well above the lactate threshold, rebounded back to baseline affect values equally or greater in as short as 10 minutes post exercise. However, participants performing 120-second intervals at severe intensities and continuous exercise at heavy intensities did not rebound back to equal baseline affect values. While affective valence during the 120-second interval and continuous sessions were not significantly different from baseline to post-exercise, this finding is in contrast to previous research, which suggests that exercise bouts typically result in an increase in post-exercise affect back to baseline values (Parfitt, Rose & Burgess, 2006; Ekkekakis, Hall & Petruzello, 2008). Therefore, it is reasonable to conclude that further investigation and explanation of various exercise modes, intensities and durations are required to successfully determine how post exercise affective valence is impacted by exercise.

Enjoyment

In-task enjoyment. While the total amount of work was the same for all conditions, total duration of exercise was different, with interval conditions being comprised of 24 minutes and the continuous condition at 20 minutes. However, participants appeared to enjoy interval training comprised of 30 and 60 seconds more than heavy continuous exercise and 120-second intervals. The 60-second interval elicited significantly greater ratings of in-task enjoyment at all time points during the exercise session than continuous exercise. This is a notable finding in that participants enjoyed exercising longer and at higher intensities during the interval conditions than during heavy continuous exercise. This finding is most likely due to the interspersed periods of

light recovery encountered during severe interval conditions comprised of 60 seconds, which has been postulated to be perceived as less work or not as monotonous than continuous heavy exercise (Greeley, 2012). Additionally, in-task enjoyment during the 60-second interval was significantly higher than the 120-second interval throughout the entire session except for the first and last time point.

Although both 60 and 120-second interval were matched for work and duration of exercise, the longer intervals encountered during the 120-second interval appeared to facilitate unfavorable ratings for in-task enjoyment during the majority of the session. This finding may be attributed to the metabolic demands required to sustain exercise at severe intensities longer than 60 seconds. Therefore, consideration of the duration that comprises the severe exercise portion of each interspersed interval should be considered when prescribing exercise designed to be pleasurable and enjoyable. It is also important to note that both the 120-second interval and continuous bout had similar ratings for in-task enjoyment and did not differ significantly from each other at any of the measured time points. Additionally, RPE was higher throughout exercise for both the 120-second interval and continuous bout in comparison to the 30 and 60-second interval. The observation of higher RPE during the 120-second interval and continuous bout corroborates previous research findings, which suggests that individuals prefer exercise conditions associated with lower RPE (Crisp, Fournier, Licari, Braham & Guelfi, 2012; Robertson & Noble, 1997), hence the 30 and 60-second interval.

In-task enjoyment was significantly greater during the 30-second interval than continuous exercise at all time points except for the second measurement. While the 30-second interval did not reach significance for in-task enjoyment in comparison to

continuous exercise at the second time point, it could simply be that the study was underpowered with only 14 participants. A larger sample size may have had the potential to increase the 30-second interval's already higher mean rating for in-task enjoyment significantly beyond the continuous bout. The 30-second interval also had significantly higher ratings of in-task enjoyment in comparison to the 120-second interval at time points 4, 5 and 6.

As previously stated, a larger sample size may have had the potential to increase the 30-second interval's already higher mean rating for in-task enjoyment significantly beyond the 120-second interval. These findings suggest that participants appear to enjoy severe interval exercise comprised of 30 seconds more than 120-second intervals and heavy continuous exercise. Therefore, the findings of this study would suggest that severe intervals comprised of 60 seconds or less should be considered when prescribing exercise designed to facilitate the greatest enjoyment, which may also be advantageous for facilitating future exercise adherence to physical activity programs (Bartlett et al., 2011).

A decline for in-task enjoyment was observed throughout all experimental conditions. However, the only experimental condition that declined significantly was the 60-second interval. This finding was odd in that enjoyment during the 60-second interval was significantly greater than the 120-second interval and continuous bout when analyzed among conditions, but appeared to be the most compromised from the beginning to the end of exercise when analyzed within conditions. While all conditions declined approximately $\frac{1}{2}$ unit, the 60-second interval appeared to decline in more of a curvilinear manner in comparison to the other conditions.

Post-exercise enjoyment. Similar to in-task assessments, Post-0 and Post-10 ratings of perceived enjoyment were both significantly greater for the 60-second interval in comparison to the 120-second interval and continuous bout. Additionally, Post-10 ratings of perceived enjoyment were significantly greater for the 60-second interval in comparison to the 120-second interval, continuous bout and 30-second interval. Therefore, these findings suggest that participants appeared to enjoy performing severe 60-second intervals more than 120-second intervals, heavy continuous exercise and potentially 30-second intervals. The results of this study parallel the findings of Bartlett and colleagues (2011) who showed that ratings of perceived enjoyment were significantly greater post exercise following interval training in comparison to continuous exercise.

Conclusions

The purpose of this study was to examine the perceptual responses to exercise by way of comparing high-intensity interval training to continuous exercise performed by overweight and sedentary individuals. The dual-mode model was utilized as the conceptual framework, which represents a dose response relationship between affective valence and exercise intensity. The perceptual responses in this study defined, as affective valence and enjoyment were generally more favorable during intervals comprised of 30 and 60 seconds in comparison to 120-second intervals and continuous exercise, which supports the previous postulation that enjoyment is linked with improvements in affective valence (Raedeke, 2007). Given the benefits of a physically active lifestyle, these results suggest that it may be most beneficial to prescribe severe intensity interval training comprised of 30 and or 60 seconds interspersed with light

recovery periods to facilitate physiological adaptations and favorable perceptual responses in overweight and sedentary individuals.

Based on these findings, avoidance of exercise prescriptions comprised of heavy intensity continuous exercise and severe intensity intervals longer than 60 seconds in duration should be considered since both affective valence and enjoyment appear to be most compromised within these domains. It has been suggested that continuous exercise bouts are perceived as boring and have the potential to negatively impact future exercise adherence (Crisp, Fournier, Licari, Braham & Guelfi, 2012; Tjønnå et al., 2008; Wisløff et al., 2007). Following the hedonic principle, individuals tend to seek experiences that provide pleasure and avoid those experiences that result in displeasure. Therefore, it is reasonable to suggest that when prescribing exercise for overweight and sedentary individuals challenged by physical activity adherence, the goal should be to design exercise bouts that are pleasurable and enjoyable.

Some of the strengths in this study include internal validity, which was preserved primarily through controlling the environment in which participants performed experimental trials. The research laboratory was setup the same way each time for participants, and communication with participants was scripted to ensure proper instructions were provided in addition to creating a sterile environment. All baseline, in-task and post-exercise variables were presented and asked in a similar manner for all participants. Industry standard metabolic testing equipment was utilized to analyze each individual's capacity and prescribe intensities for experimental conditions. An additional strength of the study was a well-trained study staff, which was attentive, intuitive and able to perform investigative duties alongside the research coordinator.

Some of the weaknesses in this study include external validity. While the findings of this study can potentially be extrapolated to other overweight and sedentary individuals, it is most likely limited to college students of a similar age, aptitude and socioeconomic status. The small sample size of the study also limits the ability to generalize the findings to the larger population. Additionally, ecological validity was poor since the study's need to control for internal validity created a sterile environment within a lab setting, which is not likely to be a setting in which exercisers regularly engage in physical activity.

Participants were required to perform exercise conditions on an unfamiliar cycle ergometer, which was considered by many to be uncomfortable. Participants were exposed to a lab setting in which they were required to face a white wall with two motivational posters along with printouts of the variables being measured (affect, exertion and enjoyment). Unlike many exercise environments that provide background music while exercising in the presence of other individuals, the lab setting required no background noise or the presence of other individuals exercising. Finally, the delta method used for prescribing exercise intensities did not allow for individuals with a VT below 40% to be matched for work at 10% [Heavy-Continuous] and 60% [Severe-Interval] of delta. Some participants required a modification of $\pm 5\%$ in order to have experimental conditions matched for total work. This is relevant, since some participants may have been exposed to a higher or lower stimulus, which could have the potential to influence their perceptual responses in a different manner than other trials prescribed at the standard 10 and 60% of delta.

The results of this study provide a foundation for future investigations interested in examining the perceptual responses to interval training and traditional continuous exercise in overweight and sedentary populations. Future studies may wish to expand their sample size to include a target population that presents greater challenges for engaging in regular exercise programs (e.g., older age groups, higher BMI, moderate to high risk for CVD). Future investigations may also wish to modify the variables that comprise interval training (e.g., exercise interval length, recovery length, exercise interval intensity, recovery intensity) in an attempt to optimize protocols that facilitate positive physiological adaptations while maximizing or preserving perceptual responses, which in turn may have the potential to favorably impact exercise adherence (Williams et al., 2008; Williams, Dunsiger, Jennings & Marcus, 2012).

Another consideration for future studies examining perceptual responses to HIIT may be to prescribe intensities at a percentage of HRmax, which could lead to more practical applications. Finally, utilizing the methodologies that comprise traditional training studies would provide an opportunity for investigators to examine physiological variables of interest as well as perceptual responses to repeated exposure of HIIT, thus determining the optimal interval training protocols for both long-term physiological adaptations and exercise program adherence. This study represents a novel attempt at examining the perceptual responses to HIIT in overweight and sedentary individuals. While the findings of this study reveal the short-term perceptual responses and benefits to HIIT, further investigation is necessary to examine the long-term implications HIIT may have on at risk populations.

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APPENDICES

Appendix A: Physical Activity Enjoyment Scale

Instructions:

Please rate how you feel at this moment about the exercise you have been doing by circling the number that seems most appropriate.

1	I enjoy it	1 2 3 4 5 6 7	I hate it
2	I feel bored	1 2 3 4 5 6 7	I feel interested
3	I dislike it	1 2 3 4 5 6 7	I like it
4	I find it pleasurable	1 2 3 4 5 6 7	I find it unpleasurable
5	I am very absorbed in this activity	1 2 3 4 5 6 7	I am not at all absorbed in this activity
6	It's no fun at all	1 2 3 4 5 6 7	It's a lot of fun
7	I find it energizing	1 2 3 4 5 6 7	I find it tiring
8	It makes me depressed	1 2 3 4 5 6 7	It makes me happy
9	It's very pleasant	1 2 3 4 5 6 7	It's very unpleasant
10	I feel good physically while doing it	1 2 3 4 5 6 7	I feel bad physically while doing it
11	It's very invigorating	1 2 3 4 5 6 7	It's not at all invigorating
12	I am very frustrated by it	1 2 3 4 5 6 7	I am not at all frustrated by it
13	It's very gratifying	1 2 3 4 5 6 7	It's not at all gratifying
14	It's very exhilarating	1 2 3 4 5 6 7	It's not all exhilarating
15	It's not at all stimulating	1 2 3 4 5 6 7	It's very stimulating
16	It gives me a strong sense of accomplishment	1 2 3 4 5 6 7	It does not give me a strong sense of accomplishment
17	It's very refreshing	1 2 3 4 5 6 7	It's not at all refreshing
18	I felt as though I would rather be doing something else	1 2 3 4 5 6 7	I felt as though there was nothing else I would rather be doing

Appendix B: Feeling Scale

Instructions: Please rate how you currently feel.

+5	Very Good
+4	
+3	Good
+2	
+1	Slightly Good
0	Neutral
-1	Slightly Bad
-2	
-3	Bad
-4	
-5	Very Bad

Appendix C: CR10 RPE Scale

Instructions: During the exercise bout we want you to pay close attention to how hard you feel the exercise work rate is. This feeling should reflect your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. Don't concern yourself with any one factor, such as leg pain, shortness of breath or exercise intensity, but try to concentrate on your total inner feeling of exertion. Try not to underestimate or overestimate your feeling of exertion; be as accurate as you can.

0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very Hard
8	
9	
10	Maximal

Appendix D: Exercise Enjoyment Scale

Instructions: Use the following scale to indicate how much you are enjoying this exercise session.

- 1: Not at all
- 2: Very little
- 3: Slightly
- 4: Moderately
- 5: Quite a bit
- 6: Very much
- 7: Extremely

Appendix E: IRB Approval Letter



DIVISION OF RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-4799
(813) 974-5638 • FAX (813) 974-5618

October 8, 2012

Marcus Kilpatrick, PhD
School of Physical Education & Exercise Science
4202 E. Fowler Ave./PED 214
Tampa, FL 33612

RE: **Expedited Approval** for Initial Review
IRB#: Pro00009451
Title: The Impact of Low Volume, High Intensity Interval Training on Perceptual Responses

Dear Dr. Kilpatrick:

On 10/8/2012 the Institutional Review Board (IRB) reviewed and **APPROVED** the above referenced protocol. Please note that your approval for this study will expire on 10/8/2013.

Approved Items:

Protocol Document(s):

[Martinez-ThesisProposal](#)

Consent/Assent Documents:

[Informed Consent .pdf](#): Please note, the informed consent/assent documents are valid during the period indicated by the official, IRB-Approval stamp located on the form – which can be found under the Attachment Tab. Valid consent must be documented on a copy of the most recently IRB-approved consent form.

Prescreen Adult Consent form granted a Waiver of Informed Consent Documentation (does not require an IRB stamp)

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR 56.110. The research proposed in this study is categorized under the following expedited review categories:

(2) Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture as follows: (a) from healthy, nonpregnant adults who weigh at least 110 pounds. For these subjects, the amounts drawn may not exceed 550 ml in an 8 week period and collection may not occur more frequently than 2 times per week; or (b) from other adults and children², considering the age, weight, and health of the subjects, the collection procedure, the amount of blood to be collected, and the frequency with which it will be collected. For these subjects, the amount drawn may not exceed the lesser of 50 ml or 3 ml per kg in an 8 week period and collection may not occur more frequently than 2 times per week.

(4) Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing.

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Your study qualifies for a waiver of the requirements for the documentation of informed consent as outlined in the federal regulations at **45 CFR 46.117 (c)**: An IRB may waive the requirement for the investigator to obtain a signed consent form for some or all subjects if it finds either: (1) That the only record linking the subject and the research would be the consent document and the principal risk would be potential harm resulting from a breach of confidentiality. Each subject will be asked whether the subject wants documentation linking the subject with the research, and the subject's wishes will govern; or (2) That the research presents no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required outside of the research context.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,



John Schinka, PhD, Chairperson
USF Institutional Review Board