CALORIC EXPENDITURE POST-ISOCALORIC BOUTS OF STEADY STATE EXERCISE
AND HIGH INTENSITY INTERVAL TRAINING

by

Toby Leigh Chambers

An Abstract
of a thesis submitted in partial fulfillment
of the requirements for the degree of Master of Science
in the Department of Nutrition and Kinesiology
University of Central Missouri

May, 2016
ABSTRACT

By

Toby Leigh Chambers

Lack of time is a common barrier to exercise participation in the general population. Lack of exercise may lead to a disruption in the energy balance equation. The purpose of the study was to determine caloric expenditure differences post-isocaloric bouts of steady state exercise and high intensity interval training. Thirteen recreationally active individuals (9 female, 4 male; 21.3±1.4yrs) participated in this study which included performing trials of steady state exercise and high intensity interval training. Trials were matched for volume of exercise based on energy used and lasted 60 minutes. The total caloric expenditure was used for data analysis. The caloric expenditure for steady state exercise trials were 261.5±74.4kcals and 284.8±83.9kcals for high intensity interval training and determined to have significant difference. In conclusion, high intensity interval training elicits statistically greater energy expenditure versus steady state exercise.
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CHAPTER ONE
INTRODUCTION

The number of overweight and obese individuals within the past decade has steadily increased within all age groups, sex/genders, and educational levels reaching an epidemic level (Lecheminant et al, 2008; Townsend, Couture, & Hazell, 2014). It is known that a routine exercise program is effective in reducing the risk factors insulin resistance and obesity which are both associated with cardiovascular disease (Lecheminant et al, 2008; Williams et al, 2013). Energy balance is the main component of obesity and it represents energy intake and energy expenditure occurring in a proportionate manner (Donnelly & Smith, 2005). Obesity is a result of disruption in energy balance triggered by an excessive energy intake contrasted by less significant energy expenditure (Donnelly & Smith, 2005). Diet is the most important component when programming a plan for weight reduction, however more than 50% of persons that lose weight through diet will regain the lost weight (Donnelly & Smith, 2005). Diet should be supplemented with physical activity and exercise to provide a long term solution to the energy balance. Physical activity and exercise stand as the most efficient way to increase energy expenditure while aiding in further declines in body weight (Donnelly & Smith, 2005). A study of 23 older obese subjects revealed that both exercise and diet may provide the means to produce weight loss (Solomon et al., 2008). Solomon et al. (2008) published findings showed that exercise could elicit significant changes in body weight, BMI, and fat mass when eucaloric and hypocaloric diets were implements. Solomon et al. (2008) showed that the hypocaloric diet paired with exercise had the greater impact in those components of weight loss as compared with the eucaloric diet paired with exercise, thus supporting the claim that diet is the most vital...
component in the energy balance equation, but also that diet and exercise can work synergistically to optimize weight loss.

Even though it is widely known that exercise has numerous health benefits, many individuals do not participate in a regular exercise routine. These individuals cite “lack of time” as the main barrier to a regular exercise routine (Gibala & McGee, 2008; Logan, Harris, Duncan, & Schofield, 2014). Traditional exercise recommendations require individuals to complete at least 30 minutes a day to physical activity. With personal, work, and family obligations the current recommendations are not feasible for the busy schedules of many individuals. High intensity interval training (HIIT) could help remedy this problem for individuals who “lack the time” for an exercise program.

Adaptations to HIIT have been similar to steady state aerobic exercise (SSE) in as little as six sessions (Burgomaster, Hughes, Heigenhauser, Bradwell, & Gibala, 2005; Gibala & McGee, 2008). Gibala and McGee (2008) found that six sessions of 4-6 Wingate protocols, which involves 30-seconds of maximal effort cycling, may significantly increase skeletal muscle oxidative capacity and endurance performance which are adaptations that are normally associated with SSE. Burgomaster et al. (2005) found an increase in skeletal muscle oxidative capacity in eight recreationally active individuals who performed a HIIT regimen. Burgomaster et al. (2005) also suggested that the 2-week HIIT program significantly increased cycle endurance capacity from 26 minutes to 51 minutes from baseline in the experimental group, while the control group saw no significant increases in endurance capacity. These HIIT sessions require significantly less time than traditional SSE routines; the reduced time commitment may lead to those individuals claiming “lack of time” to participate in a HIIT routine.
One of the benefits of SSE is the caloric expenditure during exercise, which along with proper diet may create a caloric deficit. HIIT can create a similar caloric deficit during exercise. However, the research is inconclusive on caloric expenditure post-exercise between HIIT and SSE when volume (kcals) during exercise is matched. Further research could show the possibility of HIIT being more efficient in caloric expenditure, both during and after exercise. By determining caloric expenditure post-isocaloric bouts of SSE and HIIT, it can be determined if either SSE or HIIT is superior in total caloric expenditure in a set time period. If it is determined that HIIT has similar or superior results, in terms of post-exercise caloric expenditure, then it can be concluded that HIIT can be implemented as an effective exercise modality for weight loss and weight control. Additionally, if HIIT shows similar or superior results to SSE, then it may be used as a recommendation for individuals who cite “lack of time” as a main reason for not exercising.

A review of various studies on the effect of exercise intensity, duration, and mode on the energy needs post-exercise show no common agreement between researchers (Børsheim & Bahr, 2003). Børsheim & Bahr (2003) explain that both intensity and duration play an important role in the duration and magnitude of post-exercise energy needs. The research is profoundly conflicting on whether HIIT or SSE creates a greater demand for post-exercise energy expenditure.

Further research is needed to distinguish whether HIIT or SSE demands greater post-exercise energy expenditure when volume of work is matched. Researching HIIT and SSE effects on post-exercise energy needs may create better exercise prescriptions for individuals whom are obese and/or have or are at risk for cardiovascular disease. Determination of HIIT or SSE as a superior stimulant of post-exercise caloric expenditure may lead to better individual energy balance.
Purpose

The purpose of this study is to determine if:

- HIIT elicits similar or greater post-exercise caloric expenditure to SSE, when bouts are matched for volume (kcals).
- HIIT may be recommended to individuals who cite “lack of time” as a barrier to exercise, while still obtaining similar post-exercise caloric expenditure as SSE.

Hypotheses

- Research Hypothesis I: Post-exercise caloric expenditure will be significantly greater when HIIT is utilized.
- Null Hypothesis: There will be no difference in post-exercise caloric expenditure between SSE and HIIT.

Delimitations

The delimitations of the prospective research are:

- Healthy, recreationally active individuals.
- A sample population that consists of individuals who use the Student Recreation & Wellness Center at the University of Central Missouri.
- The use of a metabolic gas analysis cart to assess caloric expenditure.
- Using a ramp protocol and cycle ergometer to measure VO2 max, SSE session, and HIIT session.
- Data collection will occur in the Human Performance Lab at the University of Central Missouri.
Limitations

The limitations of the prospective research are:

- Subjects may not follow instructions regarding prior participation activity.
- Subjects may not follow instructions regarding food consumption before participation activity.

Assumptions

The assumptions of the prospective research are:

- The test instruments are reliable and valid measures of the desired dependent variables.
- The subjects are a representation of healthy, recreationally active individuals age 18-25.
- The subjects will be able to comprehend the instructions as they are meant to be comprehended.
- The subjects will complete the maximal exercise test with a maximal effort.
- The subjects will complete the HIIT and SSE sessions with the best of their abilities.
- The investigator will be trained proficiently on the research protocol and test equipment.
CHAPTER TWO
REVIEW OF LITERATURE

The purpose of this research is to evaluate caloric expenditure post-exercise of SSE and HIIT and HIIT’s ability to be prescribed as a time saving exercise modality. This review of literature will explore the components of SSE and HIIT, the barrier of time to exercise, similar metabolic adaptations, and excess post-exercise oxygen consumption (EPOC).

Steady State Aerobic Exercise. Steady state aerobic exercise is characterized by a prolonged bout of a continuous and steady state of oxygen consumption at a moderate intensity (Williams et al., 2013). The American College of Sports Medicine recommends moderate intensity, aerobic exercise at least five days a week for at least 30 minutes (ACSM, 2014). Moderate intensity can be defined by a percentage of maximal heart rate, percentage of VO$_{2\text{max}}$, and metabolic equivalents (MET). ACSM (2014) further defines moderate intensity as activities that elicit 64-76% of age predicted maximum heart rate (APMHR), 40-60% VO$_{2\text{max}}$, or are between 3-6 METs. Moderate intensity steady state aerobic activities include but are not limited to: walking or walking at a brisk pace, ballroom dancing, shooting a round in basketball, etc. Prescription of SSE has long been accepted as a safe and valuable tool for management of obesity, insulin resistance, cardiovascular disease, dyslipidemia, and many other health factors (ACSM, 2014; Williams et al., 2013).

High Intensity Interval Training. HIIT is characterized by the execution of repeated bouts of brief, intense exercise (Little, Safdar, Bishop, Tarnopolsky & Gibala, 2011). Unlike aerobic exercises, such as long distance running and cycling, HIIT primarily depends on anaerobic metabolism. Anaerobic metabolic pathways are predominating in vigorous activities that last 30 seconds or less. During bouts of HIIT, adenosine triphosphate is resynthesized by stressing both
anaerobic and aerobic metabolic pathways (Medbø & Tabata, 1989; Tabata, Irisawa, Kouzaki, Nishimura, Ogita, & Miyachi, 1997). Examples of activities that fall under the HIIT category include, but are not limited to, the following: cycling, resistance training, sprint-interval training, circuit workouts, boxing variants, plus many others. There are currently no set guidelines for prescription volume of HIIT, but intensities for HIIT range from as low as 90% VO$_{2\text{max}}$ to as excessive as 250% VO$_{2\text{max}}$.

**Barrier of Time.** HIIT requires a significantly lower volume of work to elicit similar health benefits seen with extended bouts of SSE of greater total volume (Little et al., 2011). Volume in most cases is defined as total time, total kilojoules, or total kilocalories expended. HIIT usually involves less volume of work compared to SSE; this lower volume of work typically corresponds to a shorter time exercising. By shrinking the required time needed to complete exercise, HIIT may also eliminate the barrier of time that many allege as a deterrent for physical activity (Gibala & McGee, 2008; Logan, Harris, Duncan & Schofield, 2014).

Logan et al. (2014) hypothesized that if the time commitment barrier was eliminated, then the active population would increase because the individuals would see the health benefits without having to invest a large portion of free-time to exercise. By utilizing HIIT, individuals would no longer have to commit as much time on redundant bouts of aerobic training and more individuals may be inclined to engage in regular healthy exercise.

**Benefits of HIIT & SSE.** Utilizing HIIT or SSE has a positive effect on aerobic endurance capacity. Research shows that short bouts of sprint interval training doubled endurance capacity (time to exhaustion during cycling) and increased muscle oxidative potential in recreationally active individuals (Burgomaster, Hughes, Heigenhauser, Bradwell, & Gibala, 2005). Burgomaster et al. (2005) had subjects perform 4-7 maximum effort 30-second bouts each
session for six sessions over a two-week time span. Burgomaster et al. (2005) found that in the two-week time span muscle oxidative potential increased significantly based on citrate synthase concentrations increasing by an average of 20% from pre to post training conditions; also reported was a 100% increase in endurance capacity from pre to post training conditions when HIIT was applied. The increases can be attributed to many physiological changes seen with as little as six sessions of HIIT. This increase in aerobic capacity is similar to increases seen when SSE is used as an exercise modality. Changes in enzymatic concentrations and peroxisome proliferator-activated receptor γ coactivator (PGC-1α) are just a couple of the factors that will be discussed that lead to the increase in oxidative capacity with HIIT or SSE.

The enzymes that drive endurance performance are modified with HIIT or SSE. These modifications increase the aerobic metabolism capabilities of skeletal muscle. Research indicates that citrate synthase (CS) and 3-hydroxylacyl-CoA dehydrogenase (HADH) enzyme concentrations increased significantly in skeletal muscle with fourteen bouts of HIIT in a cohort of healthy males (Rodas, Ventura, Cadefau, Cussó, & Parra, 2000). The increase in CS was also reported in a study that included eight recreationally active individuals completing only six sessions of HIIT (Burgomaster et al., 2005). The enzyme CS plays an extremely vital role in the production of energy during the citric acid cycle, while HADH plays a vital role as a catalyzer in β-oxidation. The increase of both CS and HADH in skeletal muscle after bouts of HIIT leads to increased aerobic metabolism post-exercise. Increase action in aerobic pathways post-exercise increases energy expenditure from fatty-acid metabolism, leading to extended caloric expenditure from fat substrates (Børsheim & Bahr, 2003).

The protein PGC-1α is usually found in the cytosolic fluid in muscle cells; however when HIIT is utilized the abundance of PGC-1α in the nuclei of the muscle cells increased significantly
hours after exercise is completed (Gibala & McGee, 2008; Little et al., 2011). The PGC-1α increases the mitochondrial content by influencing a greater mitochondrial biogenesis within the muscle. This increase in muscle mitochondria leads to improved aerobic performance. Research revealed three hours into a recovery after HIIT there was increased PGC-1α in the nuclei of muscle cells overlapped to increase the expression of mitochondrial genes to a significant degree when compared to pre-exercise and 24-hour recovery periods (Little et al., 2011). This correlation led to the conclusion that HIIT can increase endurance performance because of the increase in nuclear PGC-1α which increases the mitochondrial gene expression leading to a higher muscle mitochondrial density (Little et al., 2011). PGC-1α is controlled by auto regulatory loop in mice, meaning that PGC-1α is a key regulator in its expression in skeletal muscle (Handschin, Rhee, Lin, Tarr, & Spiegelman, 2003). This self-expression by autoregulation may mean that exercise eliciting PGC-1α may lead to a further increase in PGC-1α concentrations and thus more mitochondrial biogenesis. Along with the increase in mitochondrial density, PGC-1α also drives the fiber type in muscle to change from Type II to Type I, which is another attribute to why HIIT increases aerobic endurance without having to commit the time needed to see these adaptations from traditional SSE (Gibala & McGee, 2008). In as little as six sessions of 15 minutes using HIIT, these myofibrils components change from Type II to Type I, whereas with traditional SSE an individual would be recommended 30-60 minutes of their time on most days of the week to see such changes (Gibala & McGee, 2008).

Research on sixteen active males also revealed similar initial muscular adaptations to SSE when HIIT was utilized. In this study the subjects were split into a SSE group and HIIT group, where the SSE performed 90-120 minutes of continuous cycling at around 65% VO₂peak while the HIIT group performed 4-6 ‘all out’ supramaximal cycling bouts at around 250%
VO_{2peak} totaling between 18-27 minutes per session (Gibala et al., 2006). The results showed similar significant increases before and after within the groups in muscle oxidative capacity, muscle buffering capacity and glycogen content of the HIIT and SSE groups (Gibala et al., 2006). Between all the variables measured there were no differences observed between the HIIT and SSE groups (Gibala et al., 2006). In this research the HIIT group only committed 18-27 minutes of time as compared to 90-120 minutes for the SSE group (Gibala et al., 2006). The HIIT group spent significantly less time exercising but still reaped similar initial skeletal muscle adaptations as the SSE group.

With increases in oxidative enzymes and muscle mitochondrial gene expression increased in HIIT, an increase in fat metabolism occurs. Research done by Salvadori et al. (2014) discovered that adding bouts of HIIT to a traditional aerobic workout increased fatty acid release in obese individuals as compared to traditional aerobic training. The release of these fatty acids means that more fat may be utilized for energy production. The utilization of fats may lead to a decrease in total fat mass for an individual participating in HIIT (Salvadori et al., 2014). This discovery means that for obese individuals looking to optimize weight loss, adding bouts of HIIT or strictly utilizing HIIT for exercise may prove to be the most efficient option.

Just as SSE aids in regulating blood glucose, HIIT is proven to have the same effects on blood glucose, but in a fraction of the time. Research has shown that individuals who participate in a form of HIIT show similar, and in some cases even better, regulation of blood glucose concentrations as compared with individuals who do traditional continuous aerobic training (Ivey & Ryan, 2014; LeBrasseur, Walsh, & Arany, 2010; Russell, Nelson, & Kraemer, 2014). Regulation of blood glucose within the normative range reduces the chance of an individual forming type-2 diabetes mellitus (T2DM). Regulation of blood glucose depends on insulin
sensitivity of each individual. A decreased level of insulin sensitivity may lead to increases in fasting blood glucose and the chances of developing T2DM. A review of many works revealed that HIIT training is an effective modality to improve insulin resistance as compared with a sedentary population and is comparable with improvements seen with SSE (LeBrasseur et al., 2010). Increases in muscle mass and glycolytic capacity, which are seen with forms of HIIT, have been hypothesized to improve insulin resistance as stated by LeBrasseur et al. (2010). By increasing the cross-sectional area of skeletal muscle, it increases the amount of glucose needed to fuel contraction of the muscle, which leads to the increase of insulin sensitivity. Other research done on thirty-eight healthy men and women concluded fasting glucose levels dropped significantly (-0.23±0.08 mmol·L⁻¹) after individuals participated in a HIIT program for seven weeks (Russell, Nelson, & Kraemer, 2014).

It has been documented that SSE or HIIT increase the concentration of insulin-like growth factor-1 (IGF-1) upon completion of an exercise session. IGF-1 is interactive with insulin and may increase insulin sensitivity based on studies on mice and humans (Clemmons, 2004). When three consecutive Wingate 30-second anaerobic tests were completed, IGF-1 secretion was significantly greater post-exercise than the secretion of IGF-1 after a 10-minute bout of aerobic exercise on a treadmill (Rakover, Nemet, Meckel, Pantanowitz, Zaken, & Eliakim, 2013). The secretion of IGF-1 can aid in mediating blood glucose regulation and carbohydrate metabolism by binding to insulin and results in increased insulin sensitivity which ameliorates blood glucose regulation (Clemmons, 2004). Using HIIT may promote a greater secretion of IGF-1. Using HIIT is a proven modality to increase insulin sensitivity and may sequentially regulates blood glucose level to normative value. The improvement in insulin sensitivity is attributed to many factors that include the secretion of GH and IGF-1. By utilizing HIIT as a modality of exercise,
insulin sensitivity may be optimized and the upward trend of T2DM cases may reverse without long, drawn-out bouts of aerobic exercise.

Steady state aerobic exercise has many cardiovascular health benefits when utilized. These cardiovascular benefits are also seen with bouts of HIIT. A review by Kessler, Sisson, and Short (2012) revealed that, much like aerobic exercise, HIIT may drop systolic blood pressure and diastolic blood pressures by as much as seven percent from baseline in hypertensive individuals. A decrease in blood pressure from an elevated level is optimal for long term cardiovascular health (ACSM, 2014). Elevated blood pressure increases the stress put on the heart with each beat as it must produce more force to overcome the afterload. Regular exercise increases endothelial function and leads to endothelial adaptations that aid in better regulation of blood pressure. In certain cases some individuals saw decreases in systolic and diastolic blood pressure at rest and while active. The review also studied the effects of HIIT on blood lipid profiles. Though it is not as common as the decreases in blood pressure, the evidence suggests that HIIT may increase high-density lipoproteins as much as twenty-two percent and lower overall serum cholesterol (Kessler et al., 2012).

Research done by Logan, Harris, Duncan, and Schofield (2014) mentioned HIIT can improve the cardiometabolic risk profile (i.e.-hypertension, sedentary lifestyle, obesity, T2DM, dyslipidemia, metabolic syndrome) to a greater extent than SSE in healthy, obese, and individuals with T2DM. Logan et al. (2014) stated HIIT may be a more effective method of training for restoring vascular function in patients with heart disease. Once again HIIT proves to be an efficient method for obtaining the same cardiovascular benefits that are experienced with aerobic exercise.
HIIT training also improves anaerobic capacity by improving the enzyme concentrations associated with anaerobic metabolism (Costill, Coyle, Fink, Lesmes, & Witzmann, 1979; Rodas, Ventura, Cadefau, Cussó, & Parra, 2000). Research on the effects of enzyme concentrations pre and post-exercise with 30 second ‘all-out’ bouts of knee-extensor exercises discovered increased activity of glycolytic and ATP-PCr metabolic enzyme concentrations of phosphorylase (pre-18.1±2.0; post-19.6±1.9 μmol/g·min), creatine phosphokinase (pre-609±46; post-702±53 μmol/g·min) and phosphofructokinase (pre-61.2±2.4; post-74.6±2.8 μmol/g·min) (Costill et al., 1979). These results are further supported by research conducted by Rodas et al. (2000) that revealed similar increases in anaerobic enzyme concentrations. The utilization of HIIT shows improvements in both aerobic and anaerobic capacities.

Cited earlier were the similar physiological benefits, but SSE and HIIT also share several of the same psychological benefits. Physical activity, no matter the type, may decrease the symptoms of depression and can be used as a natural medication for those who suffer from depression (ISSP, 1992). Also, research by International Society of Sport Psychology (1992) indicates that physical activity may generate improvements in psychological enhancement, mental well-being and self-esteem in adults. Dionigi (2007) revealed that older adults enhanced their overall well-being during bouts of HIIT; the enhanced feelings were attributed to enhanced self-efficacy and social interaction during the bouts of HIIT. Research also shows that ratings of perceived enjoyment were significantly greater when utilizing HIIT as compared to SSE despite HIIT having higher ratings of perceived exertion (Bartlett, Close, Maclaren, Gregson, Drust, & Morton, 2011). Eight males performed two running protocols consisting of six bouts of three minutes at 90% VO$_{2\text{max}}$ with active rest or 50 minutes of continuous running at 70% VO$_{2\text{max}}$ for HIIT and SSE, respectively. The results using the Physical Activity Enjoyment Scale showed
higher overall rate of perceived enjoyment following HIIT versus SSE (88 ± 6 vs. 61 ± 12) even when HIIT had a higher overall rate of perceived exertion (14 ± 1 vs. 13 ± 1) (Bartlett et al., 2011). The authors hypothesized that the increase in enjoyment seen with HIIT protocol may lead to a better adherence and long term exercise participation in patient populations (Bartlett et al., 2011). The list of psychological benefits reveals that, just like the physiological benefits, HIIT is an efficient modality of exercise to increase overall well-being without the time commitment that is required of aerobic exercise.

**Excess Post-Exercise Oxygen Consumption.** This portion of the review of literature explores the roles of duration, intensity, different populations, and exercise modality on excess post-exercise oxygen consumption (EPOC) and what EPOC means to post-exercise caloric expenditure. Upon completion of a bout of exercise there is an increase in oxygen consumption above resting levels that occurs because of an oxygen deficit created by the exercise session (Bahr & Sejersted, 1991; Børsheim & Bahr, 2003). This oxygen debt is hypothesized to be cause by the anaerobic cost to exercise seen at the beginning of SSE before a steady state of oxygen consumption is reached. Throughout any exercise, anaerobic energy pathways play a small role in providing energy for activity; the accumulation of energy from anaerobic pathways increases the oxygen debt that must be repaid once exercise has ceased. This occurrence is termed the EPOC and can potentially contribute to an increased caloric expenditure which could aid individuals in weight maintenance or weight loss; however, this is a controversy amongst researchers that has contradictory evidence (Greer, Sirithienthad, Moffatt, Marcello, & Panton, 2015). It is widely accepted that duration and intensity play a vital and synergistic role in eliciting a greater EPOC (Bahr & Sejersted, 1991; Børsheim & Bahr, 2003; Greer, Sirithienthad, Moffatt, Marcello, & Panton, 2015; Sedlock, 1991).
For over a century EPOC has been studied and over the years the causes of the oxygen debt from exercise have changed. The first studies of explaining the hypotheses of EPOC in human skeletal muscle were made from data collected on frog muscles (Hill, 1910; Hill, 1913; Hill, 1914). These studies concluded a basis of the delayed lactate oxidation as a cause of the oxygen debt that occurred after physical activity (Gaesser & Brooks, 1984). It wasn’t until the 1930’s that we gained the more accepted hypothesis for what elicits EPOC in humans. This research showed that the traditional oxygen debt could be separated into an initial fast phase and a slow secondary phase that are also called the “alactacid” and “lacacid” components, respectively (Margaria, Edwards, & Dill, 1933). The fast phase of EPOC is said to last about 60 minutes post-exercise while the slow phase of EPOC is considered the processes active beyond the one hour mark after exercise (Børsheim & Bahr, 2003) In the research from 1933 it was found removal of lactate from the blood was directly proportionate to the amount of lactate that was circulating and also that trained individuals were more capable to clear the circulating lactate than that of their untrained peers (Margaria et al., 1933). These concepts are still accepted as truths today and have been researched extensively to prove their validity. Even though the earliest concepts of EPOC are still accepted today, the overall explanation of oxygen debt and EPOC was too simplistic. Research shows that the elevated lactate elevations post-exercise may be used for oxidative ATP production or used as a source to resynthesize glycogen stores and are responsible for the fast component of EPOC (Gaesser & Brooks, 1984). Also responsible for the alactacid phase of EPOC is replenishing the oxygen stores in the blood and muscle, resynthesis of creatine phosphate, lowering of heart rate and lowering body temperature from increase caused by exercise (Børsheim & Bahr, 2003). Reported elevation of the EPOC during the slow phase is mostly caused by an increase in energy production from fatty acid oxidation after
prolonged exercise bouts (Børsheim & Bahr, 2003). This is common with prolonged bouts of exercise as substrate fuel source for energy tends to shifts from carbohydrates to fat during the activity (Bahr & Sejersted, 1991; Børsheim & Bahr, 2003). There is also evidence that supports muscle damage caused from eccentric exercise can increase EPOC for 24 hours and more due to muscle damage, which requires substrate energy to repair (Clarkson & Hubal, 2002; Fridén & Lieber, 2001; Fridén, Sjöström, & Ekblom, 1983) All of these components contribute to the EPOC seen after a bout of exercise, however it should be noted that the metabolic mechanisms responsible for EPOC are not fully understood. There are ways to increase the EPOC undergone after a bout of exercise; most notably are the exercise duration and intensity.

**Effects of Exercise Intensity & Duration on EPOC.** Although the claim that an elevated EPOC can create a significant difference in the energy balance equation is controversial, there is a significant amount of research that shows that intensity and duration have a significant impact on EPOC. The use of higher intensities and higher durations may be a key part in assuring that EPOC can have a significant effect on the energy balance equation.

One study revealed a greater slow component of EPOC after longer durations of exercise (Hagberg, Mullin, & Nagle, 1980b). This study had eighteen males exercise at 50, 60, and 80% of their VO$_{2max}$ for durations of 5 and 20 minutes for each intensity. The results showed a proportion increase in the fast component of EPOC was seen with intensity of exercise but not duration (Hagberg et al., 1980b). There were no differences in the slow component of EPOC between exercise duration and intensity at 50 and 60% of VO$_{2max}$, however after the 80% intensity there was a significant difference indicating that duration has a greater effect on the slow component of EPOC (Hagberg et al., 1980b). This research was one of the earliest pieces that explored the effect of intensity and duration of exercise on the components of EPOC.
Chad and Wenger (1985) revealed duration as a primary stimulus to elevating the levels of EPOC. Chad and Wenger concluded that bouts of exercise at 30 minutes in duration resulted in a greater EPOC than those of 15 minutes in duration. The exercise was conducted at both 50 & 70% VO$_{2\text{max}}$ for both durations and in both cases the longer duration of exercise gave rise to a greater EPOC (Chad & Wenger, 1985). One interesting finding of the research was that the greatest EPOC was seen after the bout of exercise at 50% VO$_{2\text{max}}$ for the 30 minute duration. This is interesting because it indicates that the intensity may play a lesser role in EPOC while duration plays the most vital role (Chad & Wenger, 1985). To support the claims made by Chad & Wenger research that was published in 1987 also supported the idea that exercise duration factors into EPOC (Bahr, Ingnes, Waage, Sejersted, & Newsholme, 1987). Six male subjects completed bouts of exercise at varying durations of 20, 40, and 80 minutes at a constant intensity of 70% of VO$_{2\text{max}}$. It was concluded that all durations elicited a significant EPOC that lasted 12 hours but not after 24 hours and the accumulation of EPOC was greater as the duration of exercise increased (Bahr et al., 1987). This conclusion adds to the idea that exercise duration may be the primary mechanism for increases in EPOC.

Furthering the support for duration as the main component of EPOC from previous studies, research was done that concluded that longer exercise durations led to a more significant increase in core body temperature which may be a factor of EPOC (Chad & Wenger, 1988). Chad and Wenger (1988) showed that as duration increased so did the correlation between EPOC and body temperature ($r=0.64$-$0.89$) and as duration increased so did energy production from fatty-acid metabolism which may be an important factor to the slow component of EPOC (Chad & Wenger, 1988). These findings are also in line with findings from research on trained and untrained women in which the duration of exercise had the biggest impact on EPOC and
fatty-acid metabolism (Chad & Quigley, 1991). The researchers also state the importance of longer duration exercise bouts as longer duration exercise will elevate both exercise and post-exercise caloric expenditure that are related to oxygen use before and after exercise (Chad & Wenger, 1988).

To the contrary of the previously mentioned studies, there is research to support the claim that intensity is the more important factor in EPOC. Research on nine male subjects was completed using treadmill protocols at 20, 50, and 80 minutes of duration while completing each of these durations at an intensity of 30, 50, and 70% VO\textsubscript{2max}. The EPOC increased to its highest levels with both duration and intensity at its highest levels but there was not a significant difference in EPOC between durations at 30% VO\textsubscript{2max} (Gore & Withers, 1989). However, it was determined that intensity explained five times more of the EPOC variance than duration or duration multiplied by intensity (Gore & Withers, 1989). This finding shows that duration and intensity of exercise may play a synergistic role with each other on EPOC values but the intensity is the variable that is responsible for more of the increases in EPOC. This increase in EPOC with higher intensities is attributed to greater anaerobic metabolism during these activities (Gore & Withers, 1989). This research states that both duration and intensity play key roles in EPOC but intensity may be the more important factor, which is contradictory to the previous studies mentioned.

To coincide with the findings made by Gore and Wither, research completed using six male subjects revealed a longer and greater EPOC observation in exercise with increased intensities but equal duration (Bahr & Sejersted, 1991). The increase in EPOC may be attributed to the increased heart rate and blood lactate concentrations as intensity increases, however there was no observed slow component of EPOC exhibited between the conditions of this study (Bahr
& Sejersted, 1991). This led to the conclusion that a threshold of a combination of duration and intensity must be exceeded to cause the prolonged EPOC component, but the research does show that intensity may be more important to EPOC than duration.

Fatty-acid metabolism has been reported to be at the highest with lower intensity and higher duration exercise (Børsheim & Bohr, 2003; Chad & Wenger, 1988; Gore & Quigley, 1991). This is an important factor to the slow component of EPOC. Research from 1997 indicates not only a greater EPOC 3-hours post-exercise but also a higher rate of fat oxidation following exercise sessions with higher intensities but shorter durations (Phelain, Reinke, Harris, & Melby, 1997). For this research subjects completed two different exercise protocols that included a low-intensity and high-intensity methods and both sessions were matched for volume by caloric expenditure. Phelain et al. (2007) concluded that when caloric expenditure is matched, intensity may elicit greater fat oxidation and subsequently elicit a greater EPOC. Similar results were seen in later research with resistance training bouts of higher intensity having a greater EPOC when work was equal with a lower intensity bout of resistance training (Thornton & Porreiger, 2002). Bouts of resistance training and HIIT were also both shown to elicit a greater EPOC in ten moderately active men when compared to SSE when duration was controlled for showing further than intensity may be a more vital key to an increased EPOC (Greer et al., 2015).

Research investigating supramaximal exercise intensities concluded that the more volume of exercise that was completed the greater the EPOC effects would be (Bahr, Grønnerød, & Sejersted, 1992). Bahr et al. (1992) also reported an increased EPOC from resting levels with as little as three sets of two minutes of supramaximal exercise in both the fast and slow components of EPOC. Supramaximal exercise has also been shown to significantly increase post-exercise
caloric expenditure when compared to an unmatched bout of SSE, which could lead to better management of energy balance (Townsend et al., 2013). Other similar findings show that EPOC was significantly higher after supramaximal bouts of exercise than SSE when the volume of work was matched (Laforgia, Withers, Shipp, & Gore, 1997). These findings may shine light on the possibility of supramaximal exercise being used as an efficient modality to elicit greater EPOC than SSE prescriptions, possibly leading to greater total energy expenditure.

In the previously mentioned studies when work was controlled, EPOC was greater in exercises that involved higher intensities. However, in previous studies of longer durations with equal intensities it was revealed EPOC to be greater in the longer duration exercise bouts. It brings up a question of total volume of work being the greatest predictor for EPOC. Research showed that total volume of exercise may be the principal factor in magnitude of EPOC (Abboud, Greer, Campbell, & Panton, 2013; LeCheminant et al., 2008). This claim is not researched to the extent of intensity and duration of exercise as it is a relatively newer concept as compared to the roles of intensity and duration on EPOC, but for research purposes volume of exercise bouts should be kept constant when comparing intensity and duration effects of EPOC.

As research is divided on whether intensity or duration of exercise has the greater influence on EPOC, one study found no significant differences in EPOC in eighteen males between HIIT and SSE (Williams et al., 2013). It should be noted that volume of work was not matched for this research but each subject completed four Wingate anaerobic protocols during one session and 60 minutes at 65% VO$_{2\text{max}}$ during the other session and no differences in EPOC were seen (Williams et al., 2013). This may show the importance of matching volume of work of each session to each training modality as differing work volumes could be a factor in magnitude of EPOC.
Contradictory to the previous statement about equal volume being important to the validity of EPOC research, split exercise sessions of equal volume have been shown to elicit greater EPOC than traditional single-session exercise routines (Kaminsky, Padjen, & Saeger, 1990). Kaminsky et al. (1990) found that two 25 minute sessions of exercise at 70% VO$_{2\text{max}}$ had a greater caloric expenditure when compared with a single session of 50 minutes at 70% VO$_{2\text{max}}$, even though EPOC was not significantly different between the different exercise routines. This shows that even though the volume of work was equal, the split session created a greater caloric deficit which may be explained by increased fat-oxidation brought on by the rest and other factors impacting EPOC (Kaminsky et al., 1990).

**EPOC Differences between Sex & Fitness Level.** Differences in EPOC between male and female subjects are important to the research process. If any differences between sex have been reported in past research, it is vital that any prospective research must control for these variables. This also is true for individuals of different fitness levels and its contribution to EPOC.

In one research study using eight males and eight females it was determined that males and females respond similarly in EPOC (Townsend et al, 2014). Each subject in this study completed a session of HIIT using both a cycling and running protocol and the results yielded no differences in EPOC between sex and furthermore even between modes of exercise (Townsend et al., 2014). It should be noted that the volume of each session was not mentioned or was it said to be matched. This study shows that between recreationally active males and females there exist no differences in EPOC after HIIT training sessions.

As far as the effect of fitness levels on EPOC the research seems to agree upon the same idea that the more trained the individual, the faster adjustments to exercise and post-exercise oxygen needs (Brehm & Gutin, 1986; Hagberg, Hickson, Ehsani, & Holloszy, 1980a). These
studies concluded that individuals who are at higher level of aerobic fitness showed faster adjustment to exercise oxygen demands which leads to a smaller oxygen debt and EPOC (Hagberg et al., 1980a). It was also found that trained runners were able to recovery from exercise when work rate was set equal relative to VO$_{2\text{max}}$ between untrained individuals meaning the trained runners saw more rapid recovery to resting levels for heart rate, VO$_2$, V$_{CO2}$, and ventilation (Hagberg et al., 1980a).

It is vital to the validity of the research that the sample population has a similar training status in terms of fitness. If research involves a heterogeneous sample with different fitness levels, then it may skew the result and flaw the conclusion.

**Summary.** In closing the review of literature has given a background into what makes up the components of HIIT and SSE and how the two differ. The barrier of time to exercise is seen as the biggest detour to exercise participation and it is hypothesized that HIIT could remedy the time commitment needed when compared to SSE. The review also designated several metabolic and cardiovascular health benefits due to either HIIT or SSE. Also discussed were the various benefits of HIIT which are not reported with a prescription of SSE. Discussed in great detail were the effects of intensity, duration, sex, and fitness level on the different components of EPOC and how a greater EPOC creates greater post-exercise energy expenditure.
**CHAPTER THREE**
**METHODOLOGY**

**Introduction.** The methods presented were designed to determine differences between caloric expenditure in a sixty-minute time period when utilizing steady state aerobic exercise and high-intensity interval training. This study did not evaluate EPOC, but is investigating caloric expenditure post-exercise between HIIT and SSE post-exercise in a sixty minute time period. As there is an increase in EPOC there is a subsequent increase in post-exercise energy expenditure. Subjects were asked to complete a total of three visits that were used to determine differences in post exercise caloric expenditure between exercise intensities. During the first visit subjects had their anthropometric measures taken and a VO\(_{2\text{max}}\) assessment performed. Subsequent to the first visit, two additional trials were conducted at least 24 hours but no more than 72 hours apart. During the SSE trial the subjects had expired gases measured while performing thirty minutes of steady state aerobic exercise at 50% VO\(_{2\text{max}}\) wattage and also for thirty minutes of seated rest post-exercise to measure caloric expenditure. The subject laid in a reclined chair during the seated rest period. For the HIIT session subjects performed high-intensity intervals of exercise using a 3:1 paradigm of active rest-to-exercise. The bouts consisted of 90 seconds of active rest at a rate of 27% VO\(_{2\text{max}}\) wattage and 30 seconds of high-intensity exercise at a rate of 120% VO\(_{2\text{max}}\) wattage. The high-intensity exercise was set at 120% VO\(_{2\text{max}}\) wattage to complete the requirements to be considered supramaximal exercise. The active rest component was set at 27% of VO\(_{2\text{max}}\), so the subjects continued to burn calories during the active-rest period. The active rest was also set at this intensity because it makes the average intensity over each HIIT bout to about 50% VO\(_{2\text{max}}\). By programming each HIIT bout in this manner it allows for average intensity to be the same as the SSE trial. The high-intensity interval training completion
transpired when caloric expenditure matched the total calories of the steady-state aerobic exercise active period. Expired oxygen was measured for a total of sixty minutes, including active and rest to determine differences in total caloric expenditure for 60 minutes.

**Subjects.** Subjects for the research were recreationally active, collegiate males and females, ages 18-25 years from the University of Central Missouri. Recreationally active was defined as any individual whom participates in 30 minutes of continuous exercise on at least 3 days of the week. Exclusion criterion included the following: known pregnancy, known cardiovascular disease, cognitive impairment, injuries that impair ability to perform test, and unable to demonstrate readiness to participate in physical activity (PAR-Q).

**Institutional Review Board and Consent.** Prior to testing of subjects, approval from the University of Central Missouri Human Subjects Committee was obtained. In this process, the Human Subjects Committee approved an informed consent that each subject understood and signed before participation in the research study.

**Procedures.** Once consent was obtained, three individual testing sessions were scheduled. These sessions took place in the Human Performance Laboratory located in the Morrow building on campus at the University of Central Missouri. Duration between each session was at least 24 hours and no more than 72 hours. Subjects were asked to refrain from other forms of extracurricular exercise during the testing period.

During the first testing trial each subject had height (cm) and weight (kg) recorded using a stadiometer (Seca®, Los Angeles, CA) and digital scale (Befour®, Saukville, WI). Once these measures were taken, the subject then completed a VO\(_{2}\)\text{max} using a ramp protocol on an electronically braked cycle ergometer (Lode®, Netherlands). A ParvoMedics TrueMax® 2400
metabolic cart (ParvoMedics, Sandy, UT) was used to determine gas analysis during the VO$_{2\text{max}}$ testing.

Before the VO$_{2\text{max}}$ testing commenced, the metabolic cart was calibrated per manufacturer’s specifications. These calibrations were completed prior to the subject arriving for each session.

Each subject was equipped with a heart rate monitor (Polar®, Lake Success, NY) to assess heart rate increases during test progression. A facemask (Hans Rudolph®, Kansas City, KS) which allowed subjects to inspire atmospheric air and expire air into the system for gas analysis was used for this study. A ramp protocol used for assessment of VO$_{2\text{max}}$ which differed between individuals based on the estimated level of cardiovascular fitness and was designed to bring the subject to volitional exhaustion within 8-12 minutes. At the onset of testing there was a sixty second period that expired gases were collected at rest; followed by a two minute warm-up period at intensity of 50 watts and concluded in a personalized VO$_{2\text{max}}$ ramp protocol. To assess whether each subject reached a true VO$_{2\text{max}}$; termination criteria for VO$_{2\text{max}}$ testing was implemented. The criteria included reaching at least three of the following: obtainment of APMHR, respiratory exchange ratio greater than 1.10, plateauing of VO$_2$ consumption, Borg’s rate of perceived exertion greater than or equal to 17. The test ended when volitional exhaustion had been reached. Subsequently the subject performed a cool down phase. The wattage numbers determined by the VO$_{2\text{max}}$ assessment were used to calculate the workloads for the steady-state aerobic and high-intensity interval exercise sessions.

During the second trial the subject completed a thirty minute bout of SSE at 50% VO$_{2\text{max}}$ based on the wattage acquired from the VO$_{2\text{max}}$ assessment. During this trial, each subject was equipped with a heart rate monitor and gas exchange facemask for testing. The metabolic cart
was used for gas analysis and live tracking of caloric expenditure. After completing the thirty minute bout of steady state aerobic exercise the caloric expenditure was recorded and the subject stopped exercise and began the thirty minute rest period. During this rest period the subject sat quietly while reclined. Gas analysis continued for thirty minutes post-exercise. At sixty minutes caloric expenditure was recorded and completed. The final trial commenced at least 24 hours and no more than 72 hours after the second session.

The third trial encompassed each subject completing bouts of HIIT following a 3:1 active rest-to-exercise paradigm. Active rest was completed at 40% VO$_2$max for 90 seconds and the high-intensity exercise was completed at 120% VO$_2$max for 30 seconds. This paradigm was utilized until the total caloric expenditure matched the caloric expenditure during exercise of the SSE trial. Once the HIIT trial matched caloric expenditure of the SSE trial, the subject stopped exercise and began the reclined, seated rest period for the remaining sixty minutes. Similarly to the second session, the gas exchange facemask remained attached to the subject and gas analysis continued until the sixty minute mark, caloric expenditure was recorded and the subject was finished.

Heart rates were obtained throughout the SSE and HIIT trials. Documentation of average heart rates during each trial was converted into a percentage of maximal heart rate. The work rate expressed as a percentage of maximal heart rate for both SSE and HIIT can be used as a better and more practical tool for assessing intensities of SSE and HIIT.

**Statistical Analysis.** Statistics were completed using IBM® SPSS® Version 23 computer software. A paired-samples t-test was used to assess statistically significant differences in sixty minute caloric expenditure between SSE and HIIT exercise modalities.
CHAPTER 4
RESULTS

The methods of this study were designed to test the hypothesis that HIIT increases caloric expenditure post-exercise compared to SSE when volume is matched. Measurements were made in a manner that accurately determined mean differences between caloric expenditure during bouts of SSE and HIIT for a 60-minute period, which included rest. Energy expenditure during activity for SSE and HIIT was matched; the only differences came during the resting stage of the trials.

Intensities for the SSE and HIIT trials were based on preliminary VO\(_{2}\text{max}\) test that were completed using a ramp protocol on a cycle ergometer. The wattage results obtained from the VO\(_{2}\text{max}\) test were used to meet intensities required for the SSE and HIIT assessments.

The SSE trial entailed each subject cycling for 30-minutes at an intensity equal to 50% VO\(_{2}\text{max}\) wattage. After 30-minutes of SSE, the subjects began a 30-minute resting session. The HIIT trial involved each subject carrying out 90 seconds of active rest at 27% VO\(_{2}\text{max}\) wattage and 30-seconds of 120% VO\(_{2}\text{max}\) wattage. These HIIT bouts were completed until caloric expenditure during exercise matched that of the SSE trial. Once caloric expenditure during exercise was equaled, the subject completed a resting phase until the 60-minute session was completed. During the entire 60-minute session, volume of oxygen consumed was recorded and converted to kilocalories during both SSE and HIIT trials. The caloric expenditure from the 60-minute SSE and HIIT trials were used for statistical analysis. The SSE and HIIT modalities served as the independent variables for the study, while 60-minute caloric expenditure served as the dependent variable.
Thirteen subjects (9 female; 4 male) completed the study. An analysis of power determined the sample to have a statistical power of 99.1% (β=0.991). Subjects’ mean ages, heights, weights, and VO₂max are reported in Table 4.1. Caloric expenditure for the SSE and HIIT trials are reported in Table 4.2.

**Table 4.1**

Demographics for subjects (N=13)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>21.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.7</td>
<td>10.4</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>74.2</td>
<td>16.4</td>
</tr>
<tr>
<td>VO₂Max (ml/kg/min)</td>
<td>35.7</td>
<td>5.2</td>
</tr>
</tbody>
</table>

**Table 4.2**

Caloric expenditure between SSE and HIIT trials (N=13)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSE Trial Kcal Expenditure</td>
<td>261.5</td>
<td>74.4</td>
</tr>
<tr>
<td>HIIT Trial Kcal Expenditure</td>
<td>284.8*</td>
<td>83.9</td>
</tr>
</tbody>
</table>

* = denotes statistical significance, \( t(12) = 4.81, p < 0.01 \)

**Statistical Analyses**

To test the hypothesis that HIIT causes a greater caloric expenditure in a 60-minute period, a paired-samples t-test was used to determine means differences in energy expenditure between SSE and HIIT. The caloric expenditure during the HIIT was significantly greater during the 60-minute session when compared to SSE trials, \( t(12) = 4.81, p < 0.01 \).
Heart Rate Ranges

The average heart rate range from the SSE trials was calculated to be 63.4±9.8% to 79.0±9.0% of predicted maximum heart rate. The range was calculated as a percentage of APMHR. The lower average heart rate range was calculated by assessing the heart rate at two minutes of SSE exercise. The upper average for heart range was determined by the highest heart rate achieved during the SSE trial, which usually came at the 30-minute mark of the SSE session. The average heart rate range after the high-intensity bouts was 77.9±4.5% to 92.9±3.2% of APMHR. The lower average heart rate range was assessed by calculating the lowest heart rate achieved after the first 30-second bout of high intensity exercise and converting it to a percentage of age-predicted maximum heart rate. The upper range for average heart was assessed by calculating the highest heart rate achieved during the HIIT trials.

The heart rate range assessed of both SSE and HIIT trials can be used for practical application in recreational settings, such as personal workouts, personal training, and others. Since the practical availability of a metabolic cart is limited to the general population, the heart rate ranges achieved during SSE and HIIT from this research may be used for those that do not have this equipment.
CHAPTER 5
DISCUSSION

A regular exercise program can be an essential part of the energy balance equation. Participation in a regular exercise program, along with adequate diet, can assist in reducing the rising rates of obesity. However, a majority of the population fails to achieve the recommended volume of exercise and physical activity and cite a scarcity of time as the main reason. The economic use of time seen when HIIT is implemented has been shown to have the same benefits as SSE, while also eliciting additional benefits specific to HIIT and not observed with SSE. Therefore, HIIT may lead to greater rates of participation and adherence to an exercise program based on the time efficient nature of the exercise. But other considerations must be taken into account before HIIT can be considered a panacea to sedentary lifestyles.

The purpose of this study was to determine whether SSE or HIIT was superior in post-exercise energy expenditure when volume of exercise was equal in energy used. It was hypothesized that HIIT would provoke a greater post-exercise caloric expenditure than SSE. Data analysis of the present data indicates that HIIT is superior to SSE in post-exercise caloric expenditure.

The results of the present study show that HIIT induces a greater caloric expenditure post-exercise than SSE when volume of work is matched. This finding coincides with the conclusion of Laforgia et al. (1997), which found that HIIT generated a greater EPOC than SSE when exercise bouts were matched for volume.

Sixty minute caloric expenditure for SSE was 261.5±74.4 kilocalories and for HIIT it was 284.8±83.9 kilocalories. The current data indicates that, on average, the HIIT bouts burn an additional 23.3 kcals when compared to SSE. The differences in between the two were
statistically significant. The increased caloric expenditure seen with HIIT may be attributed to the reliance of anaerobic pathways used in with HIIT programs. Tabata et al. (1997) explained that HIIT protocols rely more heavily on anaerobic metabolic pathways than SSE. The dependence on anaerobic energy systems may be the reason for the greater caloric expenditure post-exercise when HIIT is used as training modality. The increase in anaerobic pathways during exercise may increase the oxygen debt created by increases in body temperature, ventilation rate, and lactate production. Increases in body temperature and ventilation rate are associated with higher production of lactate. Both SSE and HIIT produce a lactate response, however lactate production is greater in HIIT due to the dependency of anaerobic pathways to provide energy to perform the high intensity portion of the routine. Greater increases in lactate production experienced during HIIT elicits an increase in EPOC, as lactate removal is one component to EPOC. A longer sustained fatty acid metabolism is associated with HIIT post-exercise compared to SSE, which increases the level and duration of EPOC with HIIT. The increased fatty acid metabolism post-exercise and lactate production due to the factors of ventilation rate, body temperature, and exercise intensity exhibited during HIIT increase EPOC and energy expenditure post-exercise when compared to SSE.

The additional 23.3 kcals would amount to 163.1 kilocalories of excess caloric expenditure if HIIT were utilized seven times a week, instead of SSE. The additional 163.1 kilocalorie expenditure exhibited in HIIT only amounts to an additional 2.1% of a kilogram of fat loss per week when compared to SSE. If HIIT were used over SSE for a time period of one year the excess caloric expenditure would equate to a superior body fat loss of 1.1 kilograms. The increased post-exercise caloric expenditure demonstrated with HIIT can be beneficial when used over an extended period of time. Individuals become obese by gaining excess body fat over a
long period of time and this accumulation of body fat can lead to negative health consequences. The increased caloric expenditure of HIIT may be used to halt the continuation and possibly decrease body fat accumulation in obese individuals over a long period of time. Along with the possibility of better control of the energy balance equation over an extended time period, HIIT also requires less time to acquire similar energy expenditure to SSE. By having both an increased energy expenditure and reduced time commitment to SSE routines, HIIT may be a superior exercise implement for those individuals who cite “lack of time” as a constraint to exercise participation.

The average heart rate ranges during both SSE and HIIT were calculated in relation to APMHR for practical use in recreational settings. Since metabolic measurements like a metabolic cart that directly measures VO$_2$ consumption are not readily available in most recreational settings, heart rate ranges allow for simpler assessment of individuals participating in either a SSE or HIIT. During SSE trials, the average heart rate range was calculated to be 63.4±9.8% to 79.0±9.0% of APMHR. This range was fairly similar to the ACSM’s percentage of APMHR recommendations for moderate intensity exercise. The ACSM recommendations for moderate intensity exercise are 64% to 76% of APMHR (ACSM, 2014). The subjects in the current research averaged 79% of APMHR when the highest heart rate during SSE was achieved. The higher average range of APMHR from the current study exceeded ACSM recommendations for moderate intensity exercise, but the difference may be irrelevant. The slight differences in the upper average heart rate range may be attributed to inexperience within the subjects with cycling exercise and, along with this inexperience, localized muscular fatigue experienced during the prolonged exercise could have attributed to the differences noted between the upper average
range of APMHR achieved during the SSE trials of this study compared to ACSM recommendations for moderate intensity exercise.

The average heart rate range during HIIT was calculated at 77.9±4.5% to 92.9±3.2% of APMHR. To the knowledge of the author there are currently no recommendations for heart range presented as a percentage of APMHR for HIIT programs. When comparing SSE and HIIT it is clearly evident that HIIT elicits a much higher percentage of APMHR after the completion of each bout of high-intensity exercise. During the active rest portion of the HIIT the heart rate dropped minutely and transiently before the next bout of high-intensity exercise. Several subjects’ heart rates in the later bouts of HIIT were lower than previous bouts. The drop in heart rate as the HIIT bouts continued could to be attributed to a decreased ability to perform the high-intensity portion at a maximal exertion. As the bouts of HIIT continued the subjects became fatigued and were not finishing the high-intensity portions with as much ease or exertion as earlier bouts. The loss in ability may be attributed to fatigue caused by losses in anaerobic pathway substrates used to power the activity and therefore a loss in the amount of explosive, high-intensity physical exertion was able to be exerted.

There were considerations that occurred during the data collection process, which must be taken into account as these considerations may have influenced results. One consideration was the effect of the HIIT trial ending during or at the conclusion of a high-intensity bout versus ending the HIIT trial during active rest. It could be assumed that a subject finishing the HIIT trial right after a high-intensity portion could produce greater post-exercise energy cost when compared to a finishing during the active rest phase of the HIIT trial. The possibility of higher energy expenditure after a HIIT trial ending during or immediately after the high-intensity portion can’t be undermined, however only three subjects finished the HIIT trial immediately
after of during the high-intensity portion. It should also be noted that one of the subjects that finished the HIIT trial immediately after the high-intensity portion expended less kilocalories post-exercise in the HIIT trial versus the SSE trial.

Nine of the thirteen subjects that completed the study were female. The menstrual cycle can have an effect on many physiological processes, including EPOC and energy expenditure post-exercise. Matsuo, Saitoh, and Suzuki (1999) researched seven women 18-20 years of age and each completed 60 minutes of SSE exercise at 60% VO$_{2\text{max}}$ and measured EPOC and fatty-acid metabolism after the exercise bout. It was concluded that the females had greater EPOC and fatty-acid metabolism during the luteal phase versus the follicular phase of the menstrual cycle. The increase in EPOC and fatty-acid metabolism observed during the luteal phase of the menstrual cycle translates into greater energy expenditure post-exercise. The female subjects of this study completed all three trials within a six day period, which may have minimized effect of the menstrual cycle. However, the menstrual cycle phase of the female subjects may have influenced results and was not controlled for in the current study.

Recreationally active individuals were recruited for the study. Recreationally active has a broad definition and the different ranges of physical activity levels were noticed within the subjects. The criteria for recreationally active (non-sedentary) individuals is described by ACSM guidelines as participating in 30 minutes of continuous moderate intensity activity on at least three days of the week (ACSM, 2014). The nature of the definition led to some subjects being well above the minimum recommendation, while others were closer to the minimum physical activity recommendation. The disparity of physical activity levels amongst the subjects may have led to skewed results. Different activity levels between the subjects could elicit different energy expenditure and EPOC responses to SSE and HIIT trials. However, the ACSM definition of
“recreationally active” allowed for a broad range of exercise history and greater number of subjects to participate in the study.

The aforementioned considerations to the data collection and how it may have influenced results are important to comment on as they may have led to a skewing of the final results. Further research on the effects of the finishing point of a HIIT trial, menstrual cycle, and physical activity level needs to be completed to further support or refute the conclusions of the current study.

**Complications with HIIT**

The similarities and advantages of HIIT compared to SSE have been heavily and undeniably expressed in the current study. These similarities and advantages do not come without precautions that should be taken into account when pondering the use of a HIIT program. When programming an exercise regimen for a subject with heart disease, a HIIT protocol should be approached with extreme caution. Mike and Kravitz (2007) determined that HIIT and SSE had similar results in aerobic capacity improvements in subjects with coronary artery disease. This may tempt some to implement a HIIT program for time saving benefits in other patients with heart disease. However, this research was completed under clinical supervision and the HIIT bouts were prolonged and at an intensity of only 90% heart rate reserve. Any complications that may have occurred during the study had medical care ready in the case of an emergency. In a recreational setting a HIIT protocol can be extremely dangerous for individuals with heart disease. In the current study the subjects completed supramaximal bouts of HIIT at intensities above VO$_{2\text{max}}$. Intensities at a supramaximal level can lead to hemodynamic problems in patients with heart disease much faster than the 90% VO$_{2\text{max}}$ intensities. The supramaximal intensities of a HIIT protocol can induce a hemodynamic
compromise in heart disease patients in a very short amount of time. The hemodynamic imbalance induced by HIIT protocols can lead to myocardial infarction and possibly death. When programming exercise routines for individuals with known or possible heart disease, HIIT should not be resorted to as the first choice and should only be done under professional medical supervision.

Another population to consider is individuals with metabolic disease as a result of a sedentary lifestyle. Individuals suffering from metabolic disease often develop T2DM and heart disease as the disease progresses and physical activity is not changed from a sedentary level. Obesity, which is caused by excessive energy intake compared to energy expenditure, is also associated strongly with metabolic disease. Weston, Wisløff, and Coombes (2014) performed a meta-analysis that concluded that HIIT significantly increased VO$_{2\text{max}}$ by 9.1% over SSE in subjects with metabolic disease. Performing HIIT can produce greater aerobic capacity benefits in all individuals compared to SSE, but HIIT can also be dangerous and difficult for an individual with metabolic syndrome. Despite the many benefits HIIT creates for an individual with metabolic syndrome, T2DM, and obesity, the risk associated with HIIT need to be accounted for the same as patients with heart disease. The sedentary lifestyle of an individual with metabolic syndrome can make it exceedingly difficult for them to complete a HIIT session. The inability to complete the HIIT sessions may cause a decrease in exercise participation and adherence. The individual may become disheartened by the inability to complete high levels of physical exertion needed to complete HIIT sessions. Another consideration is that individuals with metabolic syndrome are at a higher risk of developing or having heart disease. The increased risk for heart disease may lead to the increased risk of myocardial infarction and death as a result of hemodynamic compromise caused by HIIT. Not only can an individual with
metabolic syndrome be deterred from exercise participation by HIIT, it may also lead to adverse cardiovascular effects for the individual with undiagnosed heart disease.

Performing HIIT can elicit similar health and fitness benefits to SSE, which makes it practical for healthy individuals seeking a time saving exercise program. Nonetheless, special considerations need to be used when a HIIT program is being considered for individuals with heart disease and metabolic disease. Neglecting to use caution when implementing a HIIT program for individuals with heart disease and metabolic syndrome could lead to discouragement to exercise participation, adverse health effects and possibly death.

Recommendations for Further Research.

1. Further research needs to be conducted that controls for the HIIT trial ending during a high-intensity portion. Research should perform methods that fix the number of bouts of HIIT with the trial ending after the active rest portion and during the other trial perform SSE until energy expenditure is matched. The research should also perform trials of HIIT that end right after the high-intensity portion and perform SSE until energy expenditure is matched. This might aid in determining if ending a HIIT workout right after the high-intensity portion has any significant effect on post-exercise energy expenditure.

2. The current research did not control for the phase of the menstrual cycle with the female subjects. Research should be directed toward determining if there is a difference between energy expenditure when performing SSE or HIIT during different phases of the menstrual cycle.

3. The current research had a discrepancy between female and male subjects. Future research should be conducted with similar methods used for the current study using more
equal proportion of females and males. Research should also be done on homogenous
groups of female and males using similar methods to the current study.

4. The criterion for “recreationally active” is too lax and further research should be
performed using more distinct parameters for different physical activity levels amongst
subjects. This may allow for better understanding of energy expenditure during and after
SSE and HIIT between different more defined activity levels.

Conclusion

The current study indicates HIIT stimulates a statistically significant increase in post-
exercise caloric expenditure compared to SSE when volume of exercise is matched. Thirteen
subjects completed the study and had their characteristics recorded, which included age, height,
weight, and VO2max (Table 4.1). Caloric expenditure was recorded after each 60-minute bout of
both SSE and HIIT protocols. The caloric expenditure averages from the SSE and HIIT trials
were used to assess mean differences using a paired-samples t-test (Table 4.2). The HIIT trials
significantly increased the post-exercise caloric expenditure when caloric expenditure during
exercise was matched with the SSE trials, \( t(12) = 4.81, p < 0.01 \). The results of the study support
the research hypothesis that HIIT produces a significantly higher post-exercise caloric
expenditure than SSE when volume of exercise (in kcals) is matched between the groups. If used
over an extended period of time, HIIT could lead to better regulation of factors contributing to
obesity including the energy balance equation. Using HIIT reduces the amount of time required
for exercise participation, while still obtaining similar health benefits of SSE including the
regulation of the energy balance equation.
REFERENCES


APPENDIX A
DATA SHEET

Name:________________________________________
Age:_______ Sex: M / F Height:__________(cm)  Weight:__________(kg)

Session 1:

VO_{2\text{max}}:____________ml/kg/min
50% of VO_{2\text{max}}:____________ml/kg/min\rightarrow_________watts
27% of VO_{2\text{max}}:____________ml/kg/min\rightarrow_________watts
120% of VO_{2\text{max}}:____________ml/kg/min\rightarrow_________watts

Session 2: Steady State Exercise @ 50% of VO_{2\text{max}} for 30 Minutes

Caloric Expenditure at 30 Minutes: ___________ Kcals
Caloric Expenditure at 60 minutes: ___________ Kcals

Session 3: High Intensity Intervals @ 120% of VO_{2\text{max}} for 30 secs. w/ 90 secs @ 27% VO_{2\text{max}}

Caloric expenditure to match for exercise: __________Kcals
Caloric expenditure after resting component at 60 minutes: __________ Kcals
Dear Toby Chambers:

Your research project, ‘Caloric Expenditure Post-Isocaloric Bouts of Steady State Exercise and High Intensity’, was approved by the University of Central Missouri Human Subjects Review Committee on 2/23/2016. You may collect data for this project until 2/23/2017. Your informed consent is also approved until 2/23/2017.

If an adverse event (such as harm to a research participant) occurs during your project, you must IMMEDIATELY stop the research unless stopping the research would cause more harm to the participant. If an adverse event occurs during your project, notify the committee IMMEDIATELY at researchreview@ucmo.edu.

The following will help to guide you. Please refer to this letter often during your project.

- If you wish to make changes to your study, submit an “Amendment” through Blackboard under the “Amendment and Renewals” tab. You may not implement changes to your study without prior approval of the UCM Human Subjects Review Committee.

- If the nature or status of the risks of participating in this research project change, submit an “Amendment” through Blackboard under the “Amendment and Renewals” tab. You may not implement changes to your study without prior approval of the UCM Human Subjects Review Committee.

- If you are nearing the expiration date for collecting data for this project (2/23/2017) and you have not finished collecting data:
  1) submit your project application via Blackboard under the “Amendment and Renewals” tab (include any revisions and/or amendments approved since you submitted your application initially)
  
  AND

  2) submit a “Renewal Report” through Blackboard under the “Final/Renewal Report” tab.

- When you have completed your collection of data, please submit the “Final Report” found on Blackboard under the “Final/Renewal Report” tab.

If you have any questions, please feel free to contact me at researchreview@ucmo.edu.

Sincerely,

Deborah J. Turnbow
Director, Sponsored Programs
University of Central Missouri

cc: sburns@ucmo.edu
Protocol Number: 406
APPENDIX C
CONSENT FORM

Identification of Researchers: This research is being done by Toby Leigh Chambers, a graduate student, and Dr. Burns, a professor. We are with the Department of Nutrition and Kinesiology at the University of Central Missouri.

Purpose of the Study: The purpose of this study is to establish if: High intensity interval training elicits similar, or greater, post-exercise caloric expenditure to steady state exercise when bouts are matched for volume (kcal's) and whether or not high intensity interval training may be recommended to individuals who cite “lack of time” as a barrier to exercise, while still obtaining similar post-exercise caloric expenditure as steady state exercise.

Request for Participation: We are inviting you to participate in this research project. It is up to you whether you would like to participate. If you decide not to participate, you will not be penalized in any way. You can also decide to stop at any time without penalty. You may withdraw your data at the end of the study.

Exclusions: You must be between the ages of 18-25 to participate in this study. You must be at a low-risk for cardiovascular disease, not be pregnant, not cognitively impaired, and demonstrate readiness for physical activity (PAR-Q).

Description of Research Method: You will participate in 3 separate visits for approximately 1 hour each visit. Your height, weight, and sex will be recorded on the first visit. Also during the first visit your VO₂max will be determined using a maximal cycle ergometer ramp protocol. In the second visit you will complete 30 minutes of steady state at 50% of your VO₂max and upon completion of the exercise will have your expired gases analyzed for an additional 30 minutes, for a total of 60 minutes. The third visit will consist of high intensity interval training. These intervals will consist of 30 seconds at 120% VO₂max and 90 seconds of active rest at 27% VO₂max. These intervals will be completed until caloric expenditure is matched with the steady state exercise session. After exercise caloric expenditure is matched, expired gases will be analyzed until the 60 minute session is complete. During the time you are cycling you will be wearing a face mask to allow us to collect and analyze your expired air while breathing.

Privacy: All of the information we collect will be confidential. We will not share your information individually but only as an aggregate of the data collected as a group average. All data will be stored in a locked office in a locked file or password protected computer. Data will be destroyed according to University of Central Missouri standards.

Explanation of Risks: The risks associated with participating in this study are similar to the risks of everyday life. As with any exercise there exists the possibility of certain changes occurring during the exercise. Risks include; delayed muscle soreness, an abnormal response of blood pressure, fainting, irregular fast or slow heart rhythm, and in rare instances, heart attack, stroke, or death. As per the American Red Cross, 911 emergency services will be contacted if subject shows signs of unconsciousness, difficulty breathing, and/or chest pain/pressure. Any medical treatments provided if an injury occurs will be at the expense of the participant. If you require medical treatment or emergency service, any associated costs will be your responsibility.

Explanation of Benefits: You will benefit from participating in this study by getting firsthand experience in physical activity research. Also you will gain knowledge of where you stand physiologically in your cardiovascular fitness.

Questions: If you have any questions about this study, please contact Toby Chambers, I can be reached at tlc78680@ucmo.edu. If you have any questions about your rights as a research participant, please contact the Human Subjects Protection Program at (660) 543-4621.

I have read this letter and agree to participate.
Signature: ___________________________________________________________
Print Name: _________________________________________________________
Date: __________________________

If you would like to participate, please sign a copy of this letter and return it to me. The other copy is for you to keep.

Please sign.