The effect of two high intensity interval training protocols on heart rate, caloric expenditure, and substrate utilization during exercise and recovery

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A Thesis

entitled

The Effect of Two High Intensity Interval Training Protocols on Heart Rate, Caloric Expenditure, and Substrate Utilization During Exercise and Recovery

By

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Submitted to the Graduate Faculty as partial fulfillment of the requirements for The Master of Science Degree in

Exercise Science

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Regular physical activity is recommended for the prevention of many chronic diseases and maintaining healthy body composition. Although the beneficial effects of regular exercise are well known and used to promote exercise videos, the claims made in many advertisements are often not validated. **PURPOSE:** To determine the effects of two different types of high intensity interval exercise protocols in respect to heart rate (HR) during exercise and recovery, pulmonary O\textsubscript{2} uptake (VO\textsubscript{2}), CO\textsubscript{2} output (VCO\textsubscript{2}), caloric expenditure (CE), and substrate utilization during recovery, and psychological impacts of exercise on feelings in trained individuals. **METHODS:** Healthy subjects (n=15, 11 F, 4 M, 21.8 ± 0.83 yrs, ± SE) participated in this study. Subjects underwent two familiarization sessions prior to data collection where they completed either the Insanity® *Plyometric Cardio Circuit* (INS) or Turbo Fire® *HIIT 30* (TF) exercises in a
randomized order. The HR was measured at rest (30 min), during exercise and recovery (60 min) and expressed as % of age-predicted maximal HR (APMHR) and peak HR. Gas exchange was measured at rest and recovery. Responses of VO\(_2\), VCO\(_2\), RER were averaged at rest and five minute intervals during recovery. The caloric equivalent value for RER was used to find CE (kcal/min) at rest and corresponding five minute intervals during recovery. **RESULTS:** There was no difference (P>0.05) in peak HR (TF: 176.8 bpm, INS: 179.7 bpm). There was no difference (P>0.05) in % APMHR reached (TF: 89.4%, INS: 90.9%). There was no difference in the amount of time spent at 61-70% (TF: 510s, INS: 630s) and 71-80% APMHR (TF: 575s, INS: 517s), but there was more time spent at 81-90% APMHR (TF: 576.4s, INS: 995s). Six out of 15 subjects reached >91%APMHR in TF, and nine out of 15 subjects in INS. The HR was higher (P<0.05) after INS (55min). The recovery HR was higher (P<0.05) than resting HR after TF and INS (60min). Values of VO\(_2\) were higher (P<0.05) after INS (25, 45min). Recovery VO\(_2\) was higher (P<0.05) than resting after INS (20 min) and TF (10 min). There were no differences (P>0.05) in VCO\(_2\) between TF and INS. Recovery VCO\(_2\) was higher (P<0.05) than resting after INS (10,40, 50-60 min) and TF (10, 40-55min). The RER was lower (P<0.05) after INS (20, 35 min). Recovery RER was lower (P<0.05) than resting after INS (10-60 min) and TF (5, 15-60 min). Values of CE was higher (P<0.05) after INS (5 min). Recovery CE was higher (P<0.05) than resting after INS (20 min) and TF (10 min). Tranquility was lower (P<0.05) after INS and TF. Physical Exhaustion was higher (P<0.05) after INS and TF, but higher (P<0.05) after INS than after TF. There were no differences (P>0.05) in Positive Engagement and Revitalization.  

**CONCLUSIONS:** Results of the HR response during exercise indicates that Insanity®
was a higher intensity workout and led to a higher recovery HR. Fat was used as a primary fuel source for the majority of recovery for Insanity® and Turbo Fire®, but more reliance was on fat after Insanity®. The CE was elevated longer after Insanity®, but was back to resting for the majority of recovery. Insanity® led to a higher level of Physical Exhaustion, but neither protocol changed the decrease in Tranquility.
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List of Abbreviations

ACE...................................................................................... American Council on Exercise
ACSM ....................................................................... American College of Sports Medicine
AIT ............................................................................................... Aerobic Interval Training
ANOVA ............................................................................................... Analysis of Variance
APMHR ................................................................. Age Predicted Maximum Heart Rate
ATP ............................................................................................... Adenosine Triphosphate

CAD ............................................................................................... Coronary artery disease
CE ............................................................................................... Caloric Expenditure
CHD ............................................................................................... Coronary heart disease
CME ............................................................................................... Continuous moderate exercise
CP ............................................................................................... Creatine Phosphate
CVD ............................................................................................... Cardiovascular disease

EFI............................................................................................... Exercise-Induced Feeling Inventory
EPOC ................................................................. Excess post-exercise oxygen consumption
ET ............................................................................................... Endurance Training

HDL ............................................................................................... High density lipoprotein
HIIT ............................................................................................... High intensity interval training
HR ............................................................................................... Heart Rate
INS ................................................................................................................................. Insanity®

MIT ............................................................................................................................. Moderate intensity training

RER ............................................................................................................................. Respiratory Exchange Ratio

RMR ............................................................................................................................. Resting Metabolic Rate

SIT ............................................................................................................................... Sprint interval training

TEM ............................................................................................................................. Thermic effect of a meal

TF .................................................................................................................................. Turbo Fire®

VCO₂ .......................................................................................................................... Carbon dioxide output

VO₂ .............................................................................................................................. Oxygen utilization

VO₂max ....................................................................................................................... Maximum oxygen utilization

VO₂peak ...................................................................................................................... Peak oxygen utilization
Chapter 1

Introduction

There is a common misconception between the use of the terms physical activity and exercise. Many believe that these terms have the same definition and can be used interchangeably, but this is not the case. Physical activity is a general term used to describe bodily movement produced by the contraction of skeletal muscle of the larger muscles and can markedly increase energy expenditure.\textsuperscript{1,2} An example of physical activity could be gardening. Exercise is defined as physical activity that is performed for the purpose of improving or maintaining physical fitness by incorporating repetitive bodily movements.\textsuperscript{1,2} An example of exercise would be running or cycling. Before exercise becomes an important aspect of an individual’s daily life, they need to be mentally ready to begin incorporating exercise into their weekly routine. The health benefits of exercise are widely recognized and they are largely a function of the physiological responses that occur during as well as after exercise. However, the psychological effects associated with performing regular exercise may be an important determinant to whether people adopt exercise as a habit, allowing health benefits to take effect.
The Transtheoretical Model of Behavioral Change identifies five stages of behavior. Depending on which stage an individual is in, there may be several reasons as to why an individual would either decide to exercise or not to exercise. Individuals have identified reasons to engage and not to engage in regular exercise. Reasons typically given to exercise include: losing weight, enjoyment, improving appearance, sense of personal accomplishment, and social involvement. Reasons given to not exercise include: lack of time, lack of motivation, not enjoyable, lack of enjoyment, and being at a low fitness level. It is clearly evident that one exercise program is not going to work for everyone, but if an individual can find an exercise program that works for them, the probability of adhering to an exercise program and staying dedicated to achieving a healthy lifestyle is much higher. Once an individual is ready to add exercise to their weekly routine then factors such as exercise duration and intensity become important considerations in beginning an exercise program.

The physiological response to exercise depends on duration and intensity of the exercise bout. Heart rate is often used as an indicator of exercise intensity. The American College of Sports Medicine (ACSM) recommends that individuals participate in cardiorespiratory exercise for 20-60 minutes a day, three to five days a week at an intensity corresponding to 70% to 94% of their maximum heart rate. American Council on Exercise (ACE) categorizes exercise based on exercise duration and CE for classifications of physical fitness. These classifications are: poor, poor-fair, fair-average, average-good, and >good-excellent. Poor physical fitness includes exercising for 20-30 minutes a day or 60-150 minutes per week. Poor-fair physical fitness includes exercising for 30-60 minutes a day or 150-200 minutes per week. Fair-average,
average-good, and >good-average physical fitness includes exercising for 30-90 minutes a day or 200-300 minutes per week. Both ACE and ACSM identify exercise duration and intensity as important components of an exercise program.

Many exercise programs are either of low to moderate intensity or high intensity. If a program is of low to moderate intensity, it is usually of a longer duration of 30 minutes or more. A program of high intensity is usually of a shorter duration of 20 minutes or less. A recent study by Kemi et al. suggests that positive effects of regular exercise could very possibly depend on the intensity and duration of exercise. With lower intensity workouts, the majority of programs involve endurance activities that allow one to exercise for an extended period of time at a relatively constant HR. The HR range to be sustained during low to moderate intensity exercise is recommended to be between 50 to 79% of an individual’s maximum HR. Some examples of lower intensity workouts may include jogging, cycling, and walking. Heart rate ranges during high intensity exercise bouts are higher than what is to be maintained in lower intensity exercise. During high intensity exercise, the HR range is recommended to be between 80-100% of an individual’s maximum HR. Since the HR range is at such a high level, the duration of time is less than what can be sustained at a lower level of intensity.

Today popular high intensity workouts include running, cycling, boot camp style classes, and interval training. Although traditional interval training has been used with low to moderate intensity exercise, high intensity exercise is gaining popularity. This type of interval training is called high intensity interval training, or HIIT. The basis of traditional interval training is to work at a lower intensity for a given amount of time with periods of recovery between segments of work. The basis of HIIT is for individuals to
work as hard as they can to achieve their maximal workload for a given amount of time with periods of recovery between segments of higher intensity work. The recovery time can be equivalent to, less or more than the time spent working at the specific high intensity. The recovery allows energy to be restored and HR to decrease so that the individual can exercise at an intensity equivalent to the initial bout of exercise. Regardless of whether the intensity of exercise is high or low, CE is a very important component to exercise and the recovery process.

Whether the individual decides to exercise at a low or high intensity, the magnitude of energy expenditure will be associated with the level of exercise intensity. The ACSM recommends a target range of 150 to 400 kcal of energy expenditure per day through exercise. The lower end of the recommendation is more representative of lower intensity exercise and is an initial goal for sedentary individuals. The higher end of the recommendation is representative of higher intensity exercise and is more appropriate for individuals with a higher fitness level. Another recommendation for CE is based on classifications of physical fitness previously discussed with duration of exercise. Poor physical fitness includes exercise that expends 500-1000 kcals per week. Poor-fair physical fitness includes exercise that expends 1,000-1,500 kcals per week. Fair-average physical fitness includes exercise that expends 1,500-2,000 kcals per week. Average-good and >good-average physical fitness includes exercise that expends more than 2,000 kcals per week. In addition to energy expenditure during exercise, there is also CE post-exercise that is reflected in the excess post-exercise oxygen consumption (EPOC) phenomenon.
When exercise ceases, oxygen uptake does not abruptly return to resting values but decreases over a period of several minutes. With the cessation of exercise, there is a relatively rapid decrease in oxygen uptake within the first two to four minutes. This initial recovery is followed by a decrease in EPOC that is considerably slower than the initial phase and may take several minutes to eventually return to resting values. Oxygen uptake can remain elevated during recovery for many reasons including: elevated HR, breathing rate, body temperature, and muscle inflammation. It is important to remember that very high intensity exercise will lead to a much higher EPOC value. A higher intensity exercise causes greater changes in HR, ventilation, and body temperature. The relationship between EPOC and exercise intensity is curvilinear, but as exercise intensity increases, there is a linear relationship between exercise intensity and EPOC. There is a consensus that varying exercise intensity and duration can affect the EPOC and substrate utilization response during the recovery after exercise.

After exercise of higher intensity, the respiratory exchange ratio (RER) has been shown to decrease, indicating a reliance on fat as the primary source for fuel. After prolonged exhausting exercise, there is an increase in the rate of the energy-requiring fatty acid cycle. This rate increase is supported by the relative shift that is from carbohydrates to fats as fuel after extended exhaustive exercise. This substrate shift after exhaustive exercise of a long duration accounts for about 10-15% of EPOC during the recovery period of exercise.

Exercise intensity and duration that is appropriate for an individual’s exercise program can differ depending on where an individual is at mentally in their health and fitness journey. This decision is also dependent on the level of physical fitness an
individual has reached, or which level of physical fitness an individual wants to progress towards. Those at a higher level of fitness will be able to exercise at a higher level of intensity than an individual at a lower level of fitness. Those who are healthy, have a high level of physical fitness, and are highly trained are usually looking for new workout programs to constantly challenge their fitness levels. New workout programs can introduce a new level of CE during and after exercise, increase metabolic responses post-exercise, and can help improve or maintain fitness levels by adding a new aspect of exercise to an exercise program. With this in mind, there have been no studies to date that have looked at the physiological effects during exercise and the metabolic and psychological effects following an exercise bout of popular high intensity at home-workout programs that can improve individuals’ level of fitness.

1.1 Purpose of study

The purpose of this study was to determine the effects of two different types of high intensity interval exercise protocols in respect to HR during exercise and recovery, VO₂, VCO₂, CE, and substrate utilization during recovery, and psychological impacts of exercise on feelings in trained individuals. The two protocols were HIIT 30 from Turbo Fire® and Plyometric Cardio Circuit from Insanity®. These protocols are both commercially available workouts that consumers can purchase.

1.2 Hypothesis

Based on different claims and advertisements made by both programs as well as personal experience, we hypothesized that the Insanity® protocol would show a higher
HR during exercise, greater CE and relative contribution from fats than carbohydrates during recovery in comparison to the Turbo Fire® protocol.
Chapter 2

Literature Review

2.1 Transtheoretical Model

According to the Transtheoretical Model of Behavioral Change, there are five stages of behavior change that describe where an individual is in their journey of incorporating daily exercise into their life. These stages are precontemplation, contemplation, preparation, action and maintenance. In the precontemplation stage, individuals are sedentary and are not considering an exercise program. In the contemplation stage, individuals are still sedentary but start to consider that exercise may be an important aspect to their life. In the preparation stage, individuals participate in some exercise, but are still mentally and physically preparing to start a program. In the action stage, individuals participate in regular exercise for less than six months. In the maintenance stage, individuals engage in regular exercise for longer than six months. Depending on what stage an individual is in, there are reasons as to why individuals decide to or not to exercise. Understanding their mind set will assist in developing an exercise program for each individual.
Establishing goals is an essential aspect of any exercise program as it maximizes program adherence. Important points to keep in mind when goal setting include: avoid setting too many goals, avoid setting negative goals, set short-term and long-term goals, set outcome and performance goals, and revisit the goals on a regular basis. The number of goals should be manageable to prevent being overwhelmed. By setting positive goals, individuals are thinking about achievement and not avoidance in an exercise program. Within each workout, it is important that short-term goals can be achieved. Revisiting goals on a regular basis can help maximize the effectiveness of exercise adherence and the process of goal setting. When goals are being made, it is important that the goals are specific, measureable, attainable, relevant and time-bound. Since many individuals exercise for weight control, the common goal is to lose overall body weight or to lose body fat. The appropriate exercise program will differ between individuals based on the specific goals they wish to achieve.

2.2 Obesity and Obesity Related Problems

Obesity has become a public health issue after decades of obesity rates increasing throughout United States. A 2012 report of The Washington Post indicates that the increasing rates of obesity are leveling off. Even with rates leveling off, obesity is still a worldwide concern in health care with the pandemic rise in overweight and obese individuals. Aside from any argument that genetics may predispose someone to becoming obese, the primary cause of obesity is a sedentary lifestyle coupled with an excessive intake of calories. In addition, this lifestyle leads to several other health risks such as hypertension, coronary artery disease (CAD), and diabetes.
Another serious condition linked with obesity is the metabolic syndrome, which is a cluster of cardiovascular risks factors and cardiometabolic abnormalities that include: blood pressure above 130/85, fasting blood sugar of 100 mg/dL or above, blood triglyceride level of 150 mg/dL or above, a low high density lipoprotein (HDL) level of less than 40 mg/dL for men and 50mg/dL for women, and abdominal circumference measurements of ≥ 40 inches for men and ≥ 35 inches for women. Having three or more out of the five attributes just mentioned determines if an individual has metabolic syndrome. Individuals with metabolic syndrome are more likely to die from coronary heart disease (CHD) compared to healthy individuals, and those who are obese and have metabolic syndrome can expect to have an increased risk of death or repeated cardiovascular events following a myocardial infarction should they survive the initial event.

Individuals who have metabolic syndrome, CHD, and are obese tend to exhibit decreased aerobic exercise capacity and fatigue easily due to a low tolerance to physical activity and exercise. High dropout rates after starting an exercise program highlight the fact that compliance with exercise programs is a widespread problem in this country. Although the form of exercise that should be prescribed is still in debate, it seems that in many instances, the better option is to start with a low to moderate intensity exercise program and eventually progress to a higher intensity program when appropriate. High intensity exercise is not the favorable option for overweight and obese individuals with cardiovascular risks. These risks associated with being obese limit the ability to safely complete an exercise routine and is detrimental to exercise adherence. There is an increased risk for sudden cardiac arrest in individuals with lower fitness levels during
a high intensity workout compared to those that are healthy, have a higher level of fitness, and are able to complete this type of exercise.\textsuperscript{17,18} However, there is a relatively new approach to exercise programming called HIIT that may prove to be of significant benefit to obese individuals.\textsuperscript{17,18} This method of exercise is applicable to overweight, obese, healthy and fit individuals allowing them to work at intervals of higher intensity than they would otherwise be able to by incorporating recovery periods of lower intensity during the exercise workout.\textsuperscript{5}

\textbf{2.3 Benefits of Exercise}

A study by Thompson et al. reported that those who engage in regular physical activity end up gaining less weight than individuals who are inactive.\textsuperscript{19} Individuals who have low fitness levels and are sedentary or overweight are capable of improving their fitness levels with longer duration exercise of low to moderate intensity.\textsuperscript{2} The lower intensity exercise is usually recommended for individuals looking to lose or control weight since it seems easier to sustain an exercise of low intensity for a longer period of time rather than an exercise of a high intensity.\textsuperscript{19} Once exercise becomes a routine, there is improved exercise capacity allowing for the ability to sustain a workload for a longer period of time as well as increasing exercise intensity.\textsuperscript{20}

As physical activity and fitness levels increase, decreases in mortality, cardiovascular disease (CVD), and increases in quality of life are typically observed.\textsuperscript{18,21} Benefits that are seen with weight loss from exercise include the prevention of type II diabetes, improvement of insulin sensitivity, and decreased clotting, lipid and fasting glucose values.\textsuperscript{16} Other benefits seen with an acute bout of exercise are reduced diastolic
and systolic blood pressure and enhanced recovery HR responses following low to high intensity exercise. Obesity experts have acknowledged a role for high intensity exercise in managing weight, and there is a growing appreciation for exercise with an interval based system to fuel adaptations in the cardiovascular and muscular systems.

There is considerable interest in exercise-induced fat loss, but the optimal exercise choice that should be used to maximize fat loss is still undetermined. It is apparent that exercise helps increase the amount of calories expended daily, creating a negative energy balance and a negative fat balance, thus helping reduce body fat and weight. Following an exercise regimen that utilizes primarily fat as its fuel source, in combination with a diet that is low in fat, is a beneficial combination for losing weight and preventing weight gain. In regard to total body fat loss, the total CE seems to be a key component. Irving et al. found that a high intensity endurance training protocol was more effective for seeing changes in body composition, such as reduced body weight, body fat percentage, and waist circumference, due to a greater CE than a lower intensity endurance training protocol. Higher exercise intensity training has also been shown to decrease and aid in preventing metabolic syndrome compared to lower levels of training.

2.4 Effectiveness of Exercise Programs

Individuals seek exercise programs that meet their physical and mental needs. Not all programs work for all individuals. Exercise programs are generally initiated for the purpose of losing or maintaining weight and improving health and fitness. Many studies have been administered to determine the advantages and disadvantages of various types of exercise programs, yet there is still controversy over which type is the most
efficient and beneficial for different individuals. Individuals who only exercise and do not change their diet, do not have the best results for weight loss or maintenance. Individuals who only change their diet, without adding exercise to their weekly routine, also do not have the best results for weight loss or maintenance. A combination of exercise and diet are the most beneficial option for weight loss and maintenance. Since various exercise programs differ in intensity and duration as well as CE and substrate utilization, different models of exercise programming will be discussed.

2.5 Low to Moderate Intensity Exercise

Many individuals who are just starting an exercise program, or using exercise primarily for health benefits rather than for athletic performance, typically participate in low to moderate intensity exercise of longer duration. With this in mind, most exercise training programs are usually carried out at low to moderate intensities. Lower intensity exercise is usually of a longer duration of 30 minutes or more. A downside to a lower intensity workout is that individuals can become bored with the exercise resulting in reduced exercise adherence. When exercise sessions of moderate intensity for 20 to 30 minutes are repeated for several weeks, there is improved endurance capacity. Exercising at a moderate intensity for six to 12 weeks creates further improvements in aerobic capacity.

Traditional endurance training, such as jogging, that incorporates lower intensities is thought to have a greater effect on muscle oxidative capacity and endurance performance. One study by Burgomaster et al., that included 20 young and healthy men and women, compared a sprint interval training (SIT) group and moderate intensity
endurance training (ET) group. This study found that the ET group completed 4.5 hours of continuous moderate intensity exercise in a week compared to only about 10 minutes in the SIT group. These results indicate that a benefit of low to moderate intensity exercise is the ability to exercise for a longer period of time without fatigue. In comparison to these results, it is suggested that there is not a difference in the rate of perceived exertion between a high intensity aerobic protocol and a moderate intensity protocol, indicating that at either intensity, subjects feel similar amounts of difficulty and fatigue.

Exercise of low to moderate intensity and duration is recommended for enhancing one’s aerobic capacity through their VO\(_{2\text{max}}\). A common finding is the absence of a continuous increase in VO\(_2\) after low intensity exercise, and it appears that an intensity above 50-60% of VO\(_{2\text{max}}\) is required to induce EPOC that may persist for several hours after exercise. A study by Borsheim et al. found that EPOC was highest after a longer duration exercise of 38 minutes at 50% VO\(_{2\text{max}}\) compared to 30 minutes at 70% VO\(_{2\text{max}}\). A study by Chad et al. found that EPOC was also greater after 50% VO\(_{2\text{max}}\) in trained and untrained individuals compared to after 70% VO\(_{2\text{max}}\). In addition to these studies, Gore et al. found that post-exercise EPOC did not increase after exercise at 30% VO\(_{2\text{max}}\) of varying durations, but the magnitude of EPOC was increased significantly after exercise at 50% and 70% VO\(_{2\text{max}}\). However, the results from a study by Sedlock et al. are not in agreement with the findings from Gore et al. Results showed that EPOC was decreased significantly from pre-exercise to post-exercise at 70% VO\(_{2\text{max}}\). The degree of EPOC after aerobic exercise is in fact very dependent on both duration and intensity of exercise.
2.6 High Intensity Exercise

High intensity exercise signifies the greatest intensity that a person can maintain for about 30 to 60 minutes at near maximal effort with the feeling of fatigue in the muscles used in the exercise. When exercising at higher intensities, it is permissible to exercise for a shorter amount of time and receive the same, if not more, benefits of longer duration exercise of lower intensity. Although metabolic work can still increase with increasing intensity of exercise, it has been suggested that HR tends to level off at about 85-90% of $\text{VO}_2\text{max}$. Alderman et al. found that there is a heightened response in HR and BP after exercise of high intensity, possibly from a delayed autonomic recovery from the exercise. Exercise of shorter duration allows higher intensity workouts to be more time efficient, and one way that this can be accomplished is through interval training. High intensity interval training is beneficial for individuals of all fitness levels looking to enhance their workouts, and is a safe option for CHD patients if they are relatively fit and stable.

Training at higher exercise intensities, especially with athletes and trained individuals of higher fitness levels, can improve the ability to supply energy aerobically and anaerobically to the exercising muscles. During high intensity exercise of short duration, the capacity for aerobic energy supply, or $\text{VO}_2\text{max}$, is critical for exercise performance. Results from Tjonna et al. indicate that high intensity exercise increases $\text{VO}_2\text{max}$ to a higher degree than exercise of a lower intensity. One study by Breil et al. looked at alpine skiers and found there was a 6% improvement in relative $\text{VO}_2\text{max}$ after HIIT workouts. Although $\text{VO}_2\text{max}$ and anaerobic threshold are difficult to improve in already trained athletes, HIIT protocols have been used to achieve higher values.
Tabata et al. found that after six weeks of high intensity intermittent exhaustive exercise, \( VO_{2\text{max}} \) was improved by 7 ml/kg/min and anaerobic capacity was increased by 28%, compared to the moderate intensity group with increases of 5 ml/kg/min and no changes in anaerobic capacity.\(^{29}\) This shows that significant improvements in anaerobic capacity is possible because of the increased need of more lactate production after training.\(^{29}\) Gorostiaga et al. had an exercise protocol of intermittent work where the work periods were near 100% of \( VO_{2\text{max}} \).\(^{31}\) This showed a large oxygen deficit by a high adenosine triphosphate (ATP) utilization from anaerobic processes followed by a high level of muscle ATP and creatine phosphate (CP) depletion and lactate production.\(^{31}\) Rognmo et al. found that high intensity exercise is greater compared to moderate intensity exercise for increasing \( VO_{2\text{peak}} \) in stable CAD patients.\(^{18}\) The results showed an improvement of 17.9% (high intensity) compared to 7.9% (moderate intensity) in \( VO_{2\text{peak}} \) indicating the importance of intensity when trying to determine increases in \( VO_{2\text{peak}} \).\(^{18}\)

During exercise, the source of substrate utilization switches to carbohydrates from fats during high intensity exercise, but it has been suggested that during the post-exercise period, more fats may be utilized as the primary fuel source.\(^{19}\) Thompson et al. found that the RER (\( VCO_2/VO_2 \)) values post-exercise were lower at some points during the recovery period of three hours signifying a higher utilization of fats.\(^{19}\) The relationship between exercise duration and the magnitude of EPOC appears to be more linear with increasing intensities of exercise.\(^9\) Given this relationship, brief intermittent bouts of exhaustive supramaximal exercise seem to cause elevated energy expenditure for several hours post-exercise.\(^9\) When looking at high intensity exercise, total post-workout CE would be higher than after low to moderate intensity exercise.\(^{19}\) Thompson et al. looked
at the amount of calories burned after a moderate intensity exercise and found that 15 kcal in additional energy were expended during the immediate post-exercise period compared to after the low intensity protocol.\textsuperscript{19} Thompson et al. also found that EPOC after high intensity exercise led to an extra 29 kcals of expenditure, compared to only 14 kcals after low intensity exercise, showing that CE was higher after high intensity exercise.\textsuperscript{19}

High intensity exercise is executed at a point that promotes relatively high rates of muscle glycogen breakdown, carbohydrate oxidation, and found to reduce glycogen utilization and lactate accumulation during match-worked exercise, improving exercise performance during tasks that mainly rely on aerobic metabolism.\textsuperscript{20,28} High intensity ET may result in greater fat loss since it induces secretion of lipolytic hormones, such as growth hormone and epinephrine, which could cause greater post-exercise energy expenditure and fat oxidation.\textsuperscript{14}

\textbf{2.7 Interval vs. Continuous Exercise}

Interval and continuous exercise can be performed at low, moderate, and high intensities. An important aspect of exercise, whether continuous or interval, is to burn an appropriate amount of calories to promote weight loss and/or maintenance. Interval and continuous exercise are used for health and fitness benefits, but there is conflicting evidence for which type is more effective for improving biochemical, physiological, and performance measures.\textsuperscript{31} One benefit of interval training is it usually takes a shorter amount of time to complete compared to continuous exercise. This is very appealing to
those that have limited time for exercise and when compared to continuous exercise, many individuals find it more motivating to have a varied program of interval training.\textsuperscript{12}

Aerobic interval training (AIT) has shown a larger reduction in cardiovascular risk factors.\textsuperscript{15} Interval training is designed to allow for rest periods to allow completion of shorter work periods at a higher intensity, challenging the ability of the heart to pump sufficient amounts of blood in comparison to a lower intensity exercise of longer duration.\textsuperscript{15} This method of exercise helps make it possible for patients with heart failure to complete short exercise intervals at a higher intensity compared to continuous exercise of the same high intensity.\textsuperscript{12}

Exercise in the form of HIIT has been shown to improve endurance capacity more effectively than submaximal training of longer duration in sedentary and recreationally active individuals.\textsuperscript{30} While HIIT workouts can be very beneficial, too many without enough recovery can induce overtraining symptoms.\textsuperscript{30} Overtraining seems to be less likely with a more continuous training program.\textsuperscript{30} Breil et al. looked at HIIT sessions with elite junior skiers and results showed that during the off season, an 11-day program of 15 HIIT sessions improved VO\textsubscript{2max}, peak power output, and power output.\textsuperscript{30} HIIT has the possibility of being safer, when scheduled correctly, than continuous training above the ischemic threshold.\textsuperscript{17} This is due to the fact that HIIT results in periods of ischemia that are intermittent instead of prolonged.\textsuperscript{17}

Continuous and interval exercise can range from low to high intensity and are both acceptable for health benefits.\textsuperscript{2} When weight loss is an issue, a higher intensity or longer duration exercise is usually the most beneficial form.\textsuperscript{2} A study by Tjonna et al.
found that AIT and continuous moderate exercise (CME) were able to decrease body weight, but AIT was superior in decreasing fatty acid movement into adipose tissue.\textsuperscript{15} According to Talanian et al., moderate intensity training (MIT) and SIT completed in a short duration are both able to produce significant training effects and health benefits.\textsuperscript{24} However, MIT performed for about an hour or a two a day can be very time consuming and hard to complete.\textsuperscript{24} SIT is executed at an all-out effort that can be very challenging and intense for those just starting an exercise program.\textsuperscript{24} Just after two weeks of HIIT performed at an intensity between MIT and SIT protocols, benefits similar to both MIT and SIT exercise programs can be seen.\textsuperscript{24}

Greater improvements in VO\textsubscript{2peak} have been shown with AIT.\textsuperscript{18} Kemi et al. compared two groups, high and moderate intensity, with the same number of running intervals.\textsuperscript{4} The high intensity group exceeded the moderate group by intensity, work performed, distance run, and amount of oxygen consumed.\textsuperscript{4} In this study, the only way to be able to match moderate intensity exercise to the volume of exercise in a high intensity interval program was to have the moderate intensity program increase the number of intervals completed.\textsuperscript{4} The increase in this study was from 25\% during the first week to 100\% when VO\textsubscript{2max} leveled off.\textsuperscript{4} Talanian et al. found that intermittent sessions at about 90\% VO\textsubscript{2peak} increased post-training whole body fat oxidation during 60 minutes of cycling at about 60\% pre-training value of VO\textsubscript{2peak}.\textsuperscript{24} This represents a classic response that is usually observed in longer endurance training studies.\textsuperscript{24}

After one to three hours of continuous moderate intensity exercise, it is apparent that fatigue will occur due to carbohydrate depletion.\textsuperscript{28} Muscle glycogen can become depleted after just 15 to 30 minutes of very high intensity interval exercise.\textsuperscript{28} A
comparison of interval exercise that alternated between 30% and 90% of VO$_{2\text{max}}$, with continuous exercise of the same duration (36 minutes) at 60% of VO$_{2\text{max}}$, showed a longer EPOC magnitude after the interval exercise.\textsuperscript{9} This shows that the interval exercise allowed for an increase in oxygen utilization and CE post-exercise based on the EPOC results.\textsuperscript{9}

Other levels of interval training as well as HIIT are very realistic types of exercise that can be used by untrained and trained individuals. Wisloff et al. found that quality of life improved more with AIT than continuous exercise, signifying that more intense exercise tends to be more rewarding.\textsuperscript{12} Intermittent exercise has a higher fatigue perception than continuous exercise.\textsuperscript{31} This can include interval exercise with powerful loads resulting in a high rate of fast twitch fiber recruitment, possibly changing motor unit recruitment patterns and causing specific biochemical adaptations in the fast twitch fibers that support an increase in VO$_{2\text{max}}$.\textsuperscript{31}

With continuous exercise, there seems to be more of a delay in the accumulation of blood lactate.\textsuperscript{31} Tabata et al. found that peak blood lactate concentration after interval training was not significantly different from the concentration seen after an anaerobic capacity test.\textsuperscript{29} In comparison to ET, SIT is generally thought to have less of an effect on muscle oxidative capacity, substrate utilization and endurance performance.\textsuperscript{23} Burgomaster et al. concluded from their study that shorter duration SIT is a time efficient strategy to bring about changes in markers of whole body and skeletal muscle carbohydrate and lipid metabolism during exercise seen with longer duration ET.\textsuperscript{23} Gibala et al. found that six sessions of shorter duration SIT and traditional longer duration ET produced similar improvements in muscle oxidative capacity, muscle
buffering capacity, and exercise performance.\textsuperscript{20} Intense interval training can be a time efficient approach to rapid muscle and performance adaptations equivalent to ET.\textsuperscript{20}

### 2.8 Caloric Expenditure

Program design needs to include specific CE goals since total CE is dependent on intensity, duration, and frequency of exercise.\textsuperscript{2} Being able to estimate CE during exercise can be very challenging with multiple factors to consider such as body height and weight, duration of exercise, and intensity of exercise.\textsuperscript{2} When exercise is of a higher intensity and/or a longer duration, the CE is greater, and when the intensity and/or duration is lower, the CE is less.\textsuperscript{2} The ACSM recommends a range of 150-400 kcal of CE per day, but the upper end is more beneficial for weight loss and maintenance.\textsuperscript{2} This upper range is superior to standard exercise in achieving weight loss and favorably changing cardiometabolic risk factors, such as insulin resistance, in overweight individuals with CHD.\textsuperscript{2,16}

When it comes to decreasing total body fat loss, total CE seems to be to a key factor.\textsuperscript{14} Exercise CE includes calories expended during exercise and post-exercise.\textsuperscript{32} Recovery CE is slightly affected when exercise is of low to moderate intensity, but at higher intensities, recovery CE may be higher.\textsuperscript{32} A review by Borsheim et al. found that brief interval bouts of exhaustive exercise elevated post-exercise energy expenditure up to four hours.\textsuperscript{9} It also appears that post-exercise CE increases after exercise bouts of short or long durations and low or high intensities might be insignificant to the energy balance for weight loss.\textsuperscript{9}
Resting metabolic rate (RMR) is an important factor of total daily energy expenditure. Poehlman et al. found that RMR is elevated in highly trained males that engage in heavy exercise and can achieve high maximal aerobic capacities. These results indicate that high levels of aerobic fitness must be achieved before an elevated RMR is attained. Elevated levels of RMR may be affected by a chronic adaptation to the trained state that has been achieved. Training of repetitive bouts of exercise may have a chronic long lasting effect on RMR based on results from Devlin et al., reviewed by Borsheim et al. Findings show that with a significantly increased EPOC value after high intensity exercise, a 3-7% increase in CE was noted 12-16 hours after a prolonged exercise bout.

Enhanced CE due to a high thermic effect of a meal (TEM), found to be higher in highly trained individuals, may explain improved increases in weight loss. It is well established that RMR declines during times of caloric restriction. It has been suggested that exercise tends to counteract this decline, but it has also been suggested that exercise may have no effect on RMR with caloric restriction. The body adapts to caloric restriction by decreasing RMR, but the addition of exercise to a weight loss regimen has been shown to reverse the reduction in RMR, or even increase RMR.

EPOC will also have an effect on CE. With higher levels of EPOC, it seems there is an increase in post-exercise CE. Although EPOC does not contribute to any energy expenditure during exercise, but the additional CE from EPOC does contributes to the overall CE. Thompson et al. found that EPOC after high intensity exercise accounted for an additional 29 kcal of CE, but EPOC after low intensity exercise only contributed an additional 14 kcal. To support the findings of Thompson et al., a study by Phelain et
al. found that the average EPOC was greater after high intensity exercise compared to low intensity exercise. Results showed that after high intensity exercise, there was an additional contribution of 41 kcals compared to only 22 kcals after low intensity exercise.

2.9 Substrate Utilization

Exercise intensity dictates whether CE is primarily from fats or carbohydrates. These two main substrates, fats and carbohydrates, are fuels that the body utilizes during rest and exercise. The RER provides information on substrate utilization during exercise, with 1.00 demonstrating carbohydrate utilization and 0.70 demonstrating fat utilization. The RER is derived from the relationship between VCO₂ and VO₂. As exercise intensity increases, the RER value will also increase. It is thought that low to moderate intensity aerobic exercise permits the body to use more fat for fuel, decreasing body fat. This concept has been challenged with the theory that the total amount of fat burned during high-intensity exercises can be the same or more than what is burned during low to moderate intensity exercises.

There is some controversy over whether fats or carbohydrates provide a greater contribution to the energy requirements during high intensity exercise compared to low intensity exercise. During exercise of increasing intensity, substrate utilization shifts from a greater reliance on fats during low intensity exercise to a greater reliance on carbohydrates during high intensity exercise. It has been suggested that after high intensity exercise there is a greater reliance on fat utilization. The study by Melanson et al. found that there is evidence of a greater reliance on fat during post-exercise with high
intensity exercise compared to low intensity exercise. After lower intensity exercise, Thompson et al. found that fat was also used as fuel during the recovery period. Individuals can burn a similar amount of calories in either high intensity exercise or low intensity exercise. To burn a similar amount of calories, lower intensity exercise needs to be of a longer duration of time, where higher intensity exercise needs to be shorter in duration of time.

The duration and intensity of exercise can determine a change in skeletal muscle substrate metabolism, one of the major changes that occurs with exercise training. Improvement of skeletal muscle fatty acid oxidation is of importance for those who are attempting to elevate fat oxidation during exercise. With longer duration ET, adaptations in whole body fat oxidation seems to occur with just a couple weeks of training. As exercise intensity increases, substrate utilization may shift from a reliance on fats during low intensity to a reliance on carbohydrates during high intensity.

Interspersed HIIT workouts can offer a short duration stimulus for endurance athletes to increase fat oxidation. In HIIT workouts, the training induced shifts in fuel during exercise are present after just seven HIIT sessions over a two week period. Exercise training with HIIT can result in an increased contribution from fatty acids for energy from adipose tissue and intramuscular sites.

The type of training, continuous, interval, low to moderate intensity, or high intensity, reflects an altered source of substrate utilization. Continuous exercise training shows increased muscle aerobic capacity. There tends to be a greater reliance upon fat as fuel and a slowing rate of carbohydrate utilization with continuous exercise. Almost
all of the energy needed for exercise at a low intensity is derived from fatty acids.\textsuperscript{28} At moderate intensities, total fat oxidation increases from intramuscular triglyceride and plasma fatty acids in highly trained people.\textsuperscript{28}

Irving et al. suggested that higher intensity exercise may be more successful than moderate intensity for assisting in fat oxidation.\textsuperscript{14} At moderate to high intensity exercise, carbohydrate oxidation must provide the energy that is not available from fat stores and as the intensity of exercise increases, carbohydrates are needed for supplemental substrate oxidation.\textsuperscript{28} During high intensity exercise there are high levels of muscle glycogen breakdown and carbohydrate oxidation occurs.\textsuperscript{28} Fat oxidation does not return to the high levels that are seen during moderate intensity exercise.\textsuperscript{28} When fatty acid availability is increased, muscle is limited in its ability to use fat oxidation during intense exercise.\textsuperscript{28}

When exercising at higher intensities, carbohydrate oxidation provides the remaining fuel that could not be met by the use of fat oxidation.\textsuperscript{28} High rates of fat oxidation are not limited by plasma fatty acid availability but are limited by the muscle’s oxidative ability.\textsuperscript{28} Since fat oxidation can only be used for half of the energy needed for exercise at 70\% VO\textsubscript{2max} and no more than a third of the energy that is needed for more strenuous exercise (\textgreater{} 85\%), the need for enough muscle glycogen becomes apparent.\textsuperscript{28}

A relative shift from carbohydrate to fat as fuel is common after prolonged exercise, and since the energy equivalent of oxygen is lower with fat compared to carbohydrates, EPOC can help explain the substrate shift.\textsuperscript{9} The substrate shift after exhaustive submaximal exercise accounts for about 10-15\% of measured EPOC.\textsuperscript{9} Substrate utilization during recovery may have an impact on body fat stores.\textsuperscript{19} It has
been suggested that higher intensity exercise results in a greater fat reliance for fuel during the post-exercise period.\textsuperscript{19} After prolonged exhausting exercise, it has been shown that there is an increase in the rate of energy that requires fatty acids as fuel.\textsuperscript{9}

Diet composition is an important consideration for substrate utilization along with the addition of exercise. Keim et al. found that the resting RER tended to be lower in a diet and exercise group, with the diet composed of 55\% ± 4\% carbohydrates, 18\% ± 2\% protein, and 27\% ± 3\% fats, compared to an exercise group during exercise.\textsuperscript{34} This shows that a larger percentage of fats were being used in the diet and exercise group throughout the exercise, and a larger percentage of carbohydrates were used in the exercise group.\textsuperscript{34} This study controlled the amount of fat consumed, but when individuals take in an excess amount of fat than is used by the body, a positive fat balance occurs and fat weight is gained.\textsuperscript{19}
Chapter 3

Methods

3.1 Subjects

This study was limited to healthy, active (i.e. involved in cardiovascular physical activity most days of the week) males and females between the ages of 18 and 40 years old. The total number of subjects was 15 with four males and 11 females (aged 22.3 ± 1.6 years). Subjects who were diagnosed with a metabolic, pulmonary and/or cardiovascular disease were not allowed to participate in this study. Current smokers or those who recently quit smoking within the last 12 months were excluded from the study. Those who participated in only resistance training, or had orthopedic related concerns, preventing completion of the protocol or increasing risk injury, were also excluded from this study. Subject selection was voluntary and was limited to those that meet these criteria. All subjects in the study met the above criteria.

3.2 Experimental Design

All subjects reported to the Cardiopulmonary and Metabolism Research Laboratory at the University of Toledo on four separate visits. During the first visit,
subjects completed the medical history questionnaire and the informed consent form approved by the University of Toledo Institutional Review Board. The informed consent form advised subjects of all potential risks involved, including the possibility of muscle soreness, injury, and myocardial infarction. Subjects were not compensated for participating in the study. Subjects were able to leave the study at any time if necessary. Basic anthropometric measurements (height and weight) and resting blood pressure were measured. The distribution of lean body mass to fat mass was determined using the air displacement method (BodPod®). Additionally, each subject was required to keep a dietary log during the study. Subjects were asked to eat consistently the day before and the day of the exercise for each time they came into the lab. With the dietary log, the subjects recorded exactly the food they consumed on these days.

Each subject underwent a randomized familiarization session on day one where they participated in the Insanity® workout Plyometric Cardio Circuit or Turbo Fire® workout HIIT 30. During the second session, each subject participated in the workout that they were familiarized with in the first session. Resting measurements of HR, VO$_2$, VCO$_2$, CE and RER were obtained for a period of 30 minutes prior to the onset of exercise. Each subject rested in a supine position for no less than 20 minutes after entering the lab to ensure they were in a resting state before taking measurements. During exercise, HR was measured using a Polar monitor that used a sensor strapped around the chest to monitor HR. At the conclusion of exercise, the same measurements that were obtained prior to exercise were measured again for an additional 60 minutes.

During the third session, each subject underwent a familiarization of the workout that was not presented in the first session. During the fourth session, each subject
participated in the workout they were familiarized with in the third session. Resting measurements of HR, VO₂, VCO₂, CE and RER were obtained for a period of 30 minutes prior to the onset of exercise. Each subject laid supine for 20 minutes when entering the lab to ensure they were in a resting state before taking measurements. During exercise, HR was measured using a Polar monitor that used a sensor strapped around the chest to monitor HR. At the conclusion of exercise, measurements obtained prior to exercise were measured for an additional 60 minutes.

The exercise test was performed at approximately the same time of the day for each subject. Each exercise test session was separated by one week and was applied in a randomized order. Each visit to the lab lasted approximately three hours.

3.3 Exercise-Induced Feeling Inventory (EFI)

The EFI, shown in Table 3.1, was used to assess how each subject perceived the workout and was administered both pre- and post-exercise. The subjects scored each of the 12 adjectives with the 0 to 4 scale. To score the EFI, there were four subscales (Positive Engagement, Revitalization, Tranquility, and Physical Exhaustion) to define an emotional state. Positive engagement was related to items 4. Enthusiastic, 7. Happy and 12. Upbeat. Revitalization was related to items 1. Refreshed, 6. Energetic, and 9. Revived. Tranquility was related to items 2. Calm, 5. Relaxed, and 10. Peaceful. Physical Exhaustion was related to items 3. Fatigued, 8. Tired, and 11. Worn-out. Since each adjective can earn up to 4 points, each subscale can have a total of 0 to 12. Totals were summed together to find each subscale score and to determine the emotional state before and after each exercise protocol.

Instructions: Please use the following scale to indicate the extent to which each word below describes how you feel at this moment in time. Record your responses by filling-in the appropriate circle next to each word.

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<td>2. Calm</td>
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<td>3. Fatigued</td>
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<td>4. Enthusiastic</td>
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<td>5. Relaxed</td>
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<td>6. Energetic</td>
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<td>7. Happy</td>
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<td>8. Tired</td>
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<td>9. Revived</td>
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<td>10. Peaceful</td>
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<td>11. Worn-out</td>
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<td>12. Upbeat</td>
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3.4 Description of the Instructional Exercise Videos

3.4.1 Insanity® Interval Training Protocol

Each subject showed up in exercise clothing. They were asked to participate in the Insanity® DVD workout, *Plyometric Cardio Circuit*. The entire workout from the DVD, the warm up, two circuits, cardio bouts, and cool down, was completed. The warm was about nine minutes, followed by a 30 second water break and stretch for about five minutes. There was another 30 second water break and the interval
training of the workout began with a circuit of about two minutes followed by a 30 second water break. The circuit was repeated two more times with 30 second water breaks, with each time involving more intensity and a faster pace. At the end of the third time through, there were two additional drills lasting about one minute and 30 seconds. After this, there was a second circuit repeated three times. Two to three additional drills followed the last repeated circuit lasting about one minute and 30 seconds. At the end, there was a cool down with stretching lasting approximately three minutes to decrease the HR. The total amount of time for this workout was 41 minutes and 35 seconds.

3.4.2 Turbo Fire® Interval Training Protocol

Each subject showed up in exercise clothing. They were asked to participate in the Turbo Fire® DVD workout, *HIIT 30*. The entire workout from the DVD was completed. The HIIT workout consisted of a warm up that is approximately three minutes. After this, there was a series of drills that were repeated. There were five drills, the first four were repeated twice and the last one was repeated three times. Before each new drill, the instructor for the workout did a practice run of the moves involved in the drill. Each drill lasted approximately one minute and the subject performed at his or her maximal effort. After the drill, they received approximately one minute of active recovery (walking, jogging in place, etc.). This sequence of approximately one minute on and one minute off continued for all of the drills. Water breaks were given during the active recovery. After the last completed drill, there was a cool down lasting approximately two or three minutes consisting of stretching and slow movements to decrease the HR. The total amount of time for this workout was 30 minutes and 36 seconds.
3.5 The Metabolic Measurement System

The Vmax System (CareFusion) was used for canopy indirect calorimetry. This calorimeter measured resting and recovery CE, VO\textsubscript{2}, VCO\textsubscript{2}, and RER. The RER was calculated using a ratio (VCO\textsubscript{2}/VO\textsubscript{2}) and used as an estimate of the contribution of carbohydrates and fats as the dominant substrate utilization. Before data collection, the Vmax system was calibrated with a syringe that was connected to the system. CO\textsubscript{2} and O\textsubscript{2} tanks were turned on to calibrate the gas flow. After calibration, the subject laid supine on a table next to the system and the gases were kept on. A canopy was placed over the subjects’ head, and the canopy adapter was connected from the canopy to the Vmax system. Data was collected pre workout for 30 minutes and post workout for 60 minutes, with the gases turned off during exercise.

3.6 Data Analysis

Measurements of HR, VO\textsubscript{2}, VCO\textsubscript{2}, CE, and RER were taken from rest and recovery after exercise, with the exclusion of the measurement of HR during exercise as well. The pre and post measurements were used to observe the effects of exercise during the 60 minute recovery period. These values were measured using the Vmax System as well as a polar HR monitor. Heart rate was measured in beats per minute (bpm) at rest, during exercise, and recovery. The VO\textsubscript{2} showed how much oxygen was being utilized in terms of L/min and VCO\textsubscript{2} showed how much carbon dioxide was produced in L/min. RER was measured as the relationship between VCO\textsubscript{2} to VO\textsubscript{2}. The RER gave a kcal value which was used to calculate CE. With this value of RER, the number of calories was determined using a kcal equivalent method. This method involves the equation, Kcal
= \text{VO}_2 \text{ (L/min)} \times \text{RER caloric equivalent (Kcal/L O}_2 \text{) x time (min)}. \text{ The Vmax system gave a value of L/min as well for RER. Table 3.2 shows the relationship between the RER value and the kcal/L O}_2 \text{ that correlates with the equation. For example, an RER value of 0.90 gives a kcal/L O}_2 \text{ value of 4.924. RER and CE were both measured for resting and recovery values, with CE measured in kcals. The EFI surveys were measured by the total scores for each category for pre and post-exercise.}

\textbf{Table 3.2:} RER equivalent table used for calculation CE.
3.7 Statistical Analysis

Exercise protocols were randomized within subjects on the days of exercise and familiarization days. Comparisons were made between pre and post measurements of two different high intensity interval training exercise protocols. A two-way analysis of variance (ANOVA) with repeated measures was used to identify a significant main effect and/or interaction in HR, VO$_2$, VCO$_2$, CE, RER, and EFI surveys between the Insanity® and Turbo Fire® protocols. A paired T-test was also used to identify any differences in the time spent at <60-70%, 71-80%, 81-90%, and >90% APMHR. A post hoc analysis was used for comparisons from the significant differences found from the two-way ANOVA and paired T-test by using a Student Neuman Kuels post-hoc test. Statistical significance was set at a priori of P ≤ 0.05. All values are expressed as mean ± SD unless stated otherwise. Data was analyzed with Sigma Stat software (Sigma Stat 3.0, Systat Software Inc., Ashburn VA).
Chapter 4

Results

4.1 Subject Demographics

The mean age of study participants (n=15, 4 M, 11 F) was 22.3 ± 1.6 years (range 20 to 27 years), mean height was 169.4 ± 10.3 cm (range 153.7 to 195.5 cm), mean weight was 68.7 ± 14.8 kg (range 47.7 to 103.2 kg), mean body fat percentage was 23.0 ± 9.3 % (range 3.5 to 34.1 %), mean systolic blood pressure (SBP) was 116.9 ± 9.7 mm Hg (range 98 to 126 mm Hg), and mean diastolic blood pressure (DBP) was 74.7 ± 6.1 mm Hg (range 64 to 84 mmHg) making the average BP 116.9/74.7 mmHg. The data for one subject was not included in data analysis due to technical difficulties with the metabolic measurement system.

4.2 Heart Rate

When expressed as the percent of age predicted maximum HR (APMHR), there was no difference in the peak value obtained between protocols (TF: 89.4%, INS: 90.9%). There was no difference in the peak HR between TF and INS (TF: 176.8 ± 13.4 bpm, INS: 179.7 ± 10.2 bpm). In addition to comparing peak HR responses, the duration
spent at exercise intensities corresponding to 61-70%, 71-80%, and 81-90% of APMHR was also compared. There was no difference in the amount of time spent at 61-70% (TF: 510s, INS: 630s) or at 71-80% (TF: 575s, INS: 517s) between protocols. However, at the highest intensity where all subjects contributed data to the intensity, a greater amount of (P<0.05) time was spent during INS (995 ± 401.7s) compared to TF (576.4 ± 214.9s) at a HR corresponding to 81-90% of APMHR. For a HR greater than 90% of APMHR, six out of the 15 subjects reached 90% or greater in TF, and nine out of the 15 subjects reached that level in INS (Figure 4-1). The HR was higher (P<0.05) after INS during the first 55 minutes of recovery compared to TF. The recovery HR was higher (P<0.05) compared to resting HR after both TF and INS. (Figure 4-2)

4.3 Oxygen Utilization (VO₂)

Values for VO₂ were higher (P<0.05) following INS compared to TF during the initial 25 minutes of recovery and again at 45 minutes of recovery. In addition, the recovery VO₂ was higher (P<0.05) compared to resting VO₂ for the first 20 minutes following INS and for the first 10 min following TF (Figure 4-3).

4.4 Carbon dioxide production (VCO₂)

There was no difference in VCO₂ between TF and INS workout protocols. Recovery values for VCO₂ were higher (P<0.05) compared to resting values during recovery from INS for the first 10 minutes and at 40 minutes in recovery, and during the last 10 minutes of recovery. The VCO₂ remained elevated above resting values after TF for the first 10 min and again from 40 to 55 minutes into recovery (Figure 4-4).
4.5 Caloric Expenditure (CE)

Values of CE were higher (P<0.05) after INS compared to TF for the first five minutes of recovery. Recovery CE values were higher (P<0.05) compared to resting after INS for the first 20 minutes of recovery and after TF for the first 10 minutes of recovery. (Figure 4-5)

4.6 Substrate Utilization (RER)

Values of RER were lower (P<0.05) after INS compared to TF for the first 20 minutes of recovery and again at 35 minutes into recovery. Recovery RER values were lower (P<0.05) compared to resting after INS from 10 minutes to the end of recovery and after TF for the first 5 minutes of recovery and again from 15 minutes into recovery to the end (Figure 4-6).

4.7 Exercise Induced Feeling Inventory

Compared to pre-exercise values, there was no difference in either Positive Engagement or Revitalization for INS and TF workout protocols (Figures 4-7 and 4-8). However, compared to pre-exercise values, there was a significant increase (P<0.05) for Tranquility and Physical Exhaustion following INS and TF; the level for Tranquility was lower (P<0.05) after INS and TF but there was no difference in Tranquility between the protocols. The level of Physical Exhaustion was higher (P<0.05) after INS and TF but the level of Physical Exhaustion was higher (P<0.05) after INS compared to after TF (Figures 4-9 and 4-10).
Figure 4-1: Time spent at % APMHR. *- significant difference between INS and TF, †- significant difference from pre/rest between protocols

Figure 4-2: HR at rest, peak, and recovery. *- significant difference between INS and TF, †- significant difference from pre/rest between protocols
**Figure 4-3:** VO₂ at rest and recovery. *- significant difference between INS and TF, †- significant difference from pre/rest between protocols

**Figure 4-4:** VCO₂ at rest and recovery. *- significant difference between INS and TF, †- significant difference from pre/rest between protocols
Caloric Expenditure

Figure 4-5: CE at rest and recovery. *- significant difference between INS and TF, †- significant difference from pre/rest between protocols

Substrate Utilization

Figure 4-6: RER at rest and recovery. *- significant difference between INS and TF, †- significant difference from pre/rest between protocols
**Figure 4-7**: Positive Engagement pre- and post-exercise. * - significant difference between Pre and Post, † - significant difference Post between protocols

**Figure 4-8**: Revitalization pre- and post-exercise. * - significant difference between Pre and Post, † - significant difference Post between protocols
**Figure 4-9:** Tranquility pre- and post-exercise. *- significant difference between Pre and Post, † - significant difference Post between protocols

**Figure 4-10:** Physical Exhaustion pre- and post-exercise. *- significant difference between Pre and Post, † - significant difference Post between protocols
Chapter 5

Discussion

The purpose of the present study was to determine the effects of two different types of high intensity interval exercise protocols, Insanity® Plyometric Cardio Circuit and Turbo Fire® HIIT 30, in respect to HR, VO₂, VCO₂, CE, and substrate utilization in trained individuals. It was hypothesized that the Insanity® protocol would result in a higher HR during exercise, greater CE and relative contribution from fats than carbohydrates during recovery when compared to the Turbo Fire® protocol. The primary findings of the present study support this hypothesis.

5.1 Exercise

The results during exercise show that the maximal intensity of exercise achieved for each of the protocols was similar due to the fact that peak HR was not significantly different between Turbo Fire® and Insanity®. However, the amount of time spent at 81-90 % APMHR did show a difference with subjects spending a more time in this range, as well as having more individuals reach time spent in 90-100% APMHR during Insanity® than Turbo Fire®. When taken together, these findings for HR indicate that Insanity® was of higher intensity overall. Although there are increased benefits from high intensity
exercise, there were no studies found to support or compare the present results for APMHR and peak HR. Individuals capable of performing exercise at the 81-90% and/or 90-100% APMHR level, may have increased levels of fitness assisting with increased fitness levels, weight loss and weight management. It appears that if this level of exercise is capable of being performed and completed, it seems to be very beneficial for increased levels of fitness and to help with weight loss and management.\textsuperscript{15,18,19,22,29-31}

### 5.2 Recovery

Both protocols resulted in an elevated HR post-exercise compared to resting values. The higher recovery HR in the Insanity® protocol demonstrated that this interval exercise workout led to a higher HR during recovery compared to the interval exercise in Turbo Fire®. These findings are in contrast from Sedlock et al.’s findings with comparing both a lower and higher intensity protocol.\textsuperscript{32} The recovery HR in the study by Sedlock et al. were not significantly different from the resting HR.\textsuperscript{32} The HR variability identified in the present study has not been reported in other studies. It is possible that if either workout was completed in a non-experimental situation, post-exercise HR would be more elevated than what was demonstrated in the present study.

The CE was elevated for a longer period of time after Insanity®, but for both Insanity® and Turbo Fire®, CE returned to resting values for the majority of recovery. The findings of the present study are similar to those of Treuth et al. who compared a high intensity group to a low intensity group.\textsuperscript{39} Treuth’s study demonstrated that the high intensity group showed a higher CE over a 24 hour period post-exercise.\textsuperscript{39} The present study included a period of lying down for 60 minutes post-exercise, which is not
consistent with post-exercise activities, as most individuals return to work, class, or running errands. For the purpose of this study, subjects were to remain supine during recovery. More activity during a recovery period from exercise may lead to a higher CE post-exercise compared to the results found in this study. However, this would not change the contribution from the prior bout of exercise to the overall CE during recovery. Higher CE from high intensity workouts can aid in the progression of weight loss in individuals. Keeping in mind that if the total CE is greater than the caloric intake on a daily and weekly basis, weight loss will occur in individuals that need to lose weight.

Multiple studies on RMR and CE have found that during exercise and post-exercise are important factors when reducing or maintaining ones’ weight. For individuals that are trying to maintain weight, keeping total CE in balance with caloric intake, will maintain their weight.

When determining RER, the change in VCO$_2$ relative to VO$_2$ is a significant consideration since this ratio ($\text{VCO}_2/\text{VO}_2$) determines RER and reflects the proportion of carbohydrate and fats to substrate utilization. Given the VCO$_2$ and VO$_2$ results, the significant differences in RER values early in recovery between Insanity® and Turbo Fire® were based on the VO$_2$ values as there were no significant VCO$_2$ differences. This finding is consistent with the HR data as well. Results of VO$_2$ during recovery indicate that Insanity® maintained a higher level of VO$_2$ for the beginning of recovery. The RER values were below resting values after Turbo Fire® and Insanity® for the majority of recovery. At rest, subjects utilized a mixture of carbohydrates and fats as fuel for both protocols. In comparison to rest, carbohydrate utilization was increased initially followed by a mixture of carbohydrate and fat utilization for Insanity® and Turbo Fire®. Fat was
used as a primary fuel source for the majority of recovery for Insanity® and Turbo Fire®, but there was a greater reliance on fat as fuel following the Insanity® workout. The results from the present study did not compare to the protocols of studies that measure RER values post-exercise of higher intensity.

5.3 EFI Survey

The EFI survey results indicated that neither Insanity® nor Turbo Fire® caused a change in the level of Positive Engagement or Revitalization, but did show a difference in Tranquility and Physical Exhaustion. Subjects had a higher level of Tranquility before exercising in comparison to post-exercise, but neither protocol was more successful at changing the level of Tranquility. In terms of Physical Exhaustion, subjects started out with similar levels of Physical Exhaustion before Insanity® and Turbo Fire®. Post-workout surveys indicate that subjects felt more physically exhausted after completing the Insanity® protocol. There are no present studies found on how different exercise protocols affect how individuals feel post-exercise compared to pre-exercise.

5.4 Limitations

One limitation of this study was not using a controlled diet for the subjects. With a controlled diet, RER results could have been calculated from the exact amount of fats, carbohydrates and proteins ingested the day of and day before exercise. An additional limitation was not being able to measure the metabolic responses (VO₂, VCO₂, CE, and RER) during exercise, therefore they could not be compared to rest and recovery values. This limitation may be overcome in future studies by use of a metabolic measurement system that uses telemetry to report values. In this study, the protocols involve a
considerable amount of movement and rapid changes in body position that would have made measuring metabolic responses very uncomfortable for subjects. We also did not include a low or moderate intensity protocol to compare to the high intensity protocols. With a lower intensity protocol, a difference could have been shown between the two levels of intensity with the values measured in the study.

A recommendation for a future study would be to assess HR and metabolic effects during exercise and recovery in the continuous workouts from both Insanity® and Turbo Fire®. Another suggestion for a future study would be a comparison of other Beachbody® programs, such as Insanity: The Asylum®, Turbo Jam®, P90X®, and P90X2®. An additional study could compare the two present protocols from Insanity® and Turbo Fire® to a cycling or treadmill protocol of varying intensities to measure the variables of HR, CE, RER, VO₂, VCO₂ and EFI surveys. Since the current study utilized a young and healthy population, a comparison to a middle aged or older population may also be attempted.

5.5 Practical Applications

An inquiry that arises from this study is which protocol would be considered to be the “better” workout. Based on the results from the present study, both workouts are beneficial programs to use for weight loss or maintenance, and achieving a new level of fitness. When thinking of purchasing Insanity® or Turbo Fire®, there are factors to consider, such as, cost and composition of the exercise program. At the time of the study, the cost for Turbo Fire® was $119.70 and the cost for Insanity® was $119.85. Prior to
purchasing a program, individuals should consider the composition of the program, in addition to cost, and determine if they find it self-motivating so that they will adhere to it.

The Insanity® program includes interval, continuous, core and recovery workouts. The Turbo Fire® program includes HIIT, continuous, flexibility, core and strength training workouts. Based on the subjects’ feedback, if one is looking for more variety of movements with fun music, then Turbo Fire® would be the recommended program. If music isn’t a priority or if one is looking for intense motivation, then Insanity® would be a better choice. When looking for a good exercise program that is time efficient and effective, either workout program would be valuable.

5.6 Conclusion

In summary, this study has demonstrated that Insanity® resulted in a higher level of intensity based on HR, higher amount of recovery CE, and used more fat as a fuel source for a longer period of time in recovery. The EFI survey results suggest that Insanity® leads to a higher level of physical exhaustion. Although Insanity® demonstrated these results, utilizing Insanity® or Turbo Fire® for weight control and fitness are both acceptable programs. The key to fitness is continuing to adhere to the exercise program that is prescribed. If an individual is looking for a challenge and wants to incorporate high intensity exercise, then these programs would be beneficial for exercise adherence. If high intensity is not appealing to an individual, then exercise of lower types of intensity would be more appropriate for exercise adherence.
References


7. McKay BR, Paterson DH, Kowalchuk JM. Effect of short-term high-intensity interval training vs. continuous training on O-2 uptake kinetics, muscle


