# HIGH-INTENSITY INTERVAL TRAINING VS. SUPERSET TRAINING: A COMPARISON OF ENERGY EXPENDITURE

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**Title**

High-Intensity Interval Training vs. Superset Training: A Comparison of Energy Expenditure

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

**MASTER OF SCIENCE**

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## ABSTRACT

The purpose of this study was to compare energy expenditure between high intensity interval training (HIIT) and agonist-antagonist (SUPER) resistance training (RT) exercise protocols. Twelve males (23.91 ± 3.58 years) with at least six months of RT experience were recruited for the study. Each participant completed both exercise protocols while $VO_2$, lactate, respiratory exchange ratio (RER), heart rate (HR), and rating of perceived exertion (RPE) were measured. Significant differences were seen in RPE, RER, aerobic, anaerobic, and total overall energy expenditure when comparing protocols. There were no significant differences in $VO_2$ or HR. Rest interval length and volume load can play a part in energy expenditure, but whether other variables are affected has yet to be shown when comparing HIIT to SUPER. In this study HIIT elicited a higher total energy expenditure than SUPER despite an overall shorter duration and a lower one-repetition maximum percentage for each exercise.

## ACKNOWLEDGEMENTS

I would like to thank Dr. Donna Terbizan, Dr. Kyle Hackney, and Dr. Shannon David for assisting me in the development and completion of this research study. I would also like to thank my research assistants, Zachary Wyatt and Sean Mahoney, for assisting me in the recruitment of participants and the collection of data throughout the study. Lastly, I would like to thank the participants of this study for sacrificing their time to help the authors of this study complete their research.

## DEDICATION

I dedicate this thesis to my family. Their support and encouragement has driven me to accomplish many personal, educational, and professional goals.

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## LIST OF ABBREVIATIONS

ACSM……………………..American College of Sports Medicine

BPM……………………….Beats per minute

HIIT………………………..High Intensity Interval Training

HR…………………………Heart Rate

Kcal………………………..Kilocalorie

Mm:ss……………………..Minutes and Seconds

Mmol…………………........Millimole

One-RM…………………...One-Repetition Maximum

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

RI…….…………………….Rest Interval

RPE………………………..Rate of Perceived Exertion

RT…………………………Resistance Training

SUPER……………………Superset Training

VL…………………………Volume Load

$VO_2$Max…………………..Maximum Oxygen Consumption

# CHAPTER I. INTRODUCTION

Muscle strength and endurance are necessary for completion of day-to-day activities and to ensure success in athletic competition and exercise training (Astorino, Allen, Roberson, & Jurancich, 2012). Resistance training (RT) is a well-recognized method for improving health and fitness levels for most populations (Bloomer, 2005; Hunter, Fisher, Bryan, & Zuckerman, 2012; Robergs, Gordon, Reynolds, & Walker, 2007; Uchida et al., 2009). RT is a form of physical activity that is designed to improve muscular fitness by exercising a muscle or muscle group against external resistance (Esco, 2013). There are multiple forms of RT, each of which is designed to meet the specific goals or needs of the participants using them. There are various aspects that can be altered when completing resistance training. Among these are sets, repetitions, external resistance (e.g. weight), rest intervals, and exercise order. When these RT variables are used correctly they can help people achieve goals related to muscular endurance, hypertrophy, weight loss, weight gain, flexibility, and body composition. Although there is a large amount of research that has used RT to study results relating to fitness, research has yet to compare high-intensity interval training (HIIT) to reciprocal supersets (SUPER), also known as agonist-antagonist superset training.

HIIT has recently been used as an alternative to traditional endurance training to alter cardiorespiratory fitness, as represented by maximal oxygen uptake ($VO_2max$) (Astorino et al., 2012). Much of the active population is familiar with traditional resistance training, which involves completing a set of repetitions to failure followed by an adequate rest period before subsequent bouts of the same exercise (Kelleher, Hackney, Fairchild, Keslacy, & Ploutz-Snyder, 2010). In contrast, HIIT RT involves repeatedly exercising at a high intensity for 30 seconds to several minutes, separated by 1-5 minutes of recovery (either no or low intensity exercise) (Shiraev & Barclay, 2012). There have been multiple studies completed showing the health benefits of participating in HIIT exercise programs for athletes as well as the general population. Many of the HIIT studies conducted thus far consist of exercise programs using ergometer bikes and treadmills. For this study only RT exercises were used; no traditional forms of endurance training were involved (e.g. running, cycling). SUPER exercise programs consist of performing two consecutive exercises on opposing muscle groups while limiting the rest duration between exercises (Kelleher et al., 2010). SUPER programs are commonly used by athletes and other RT participants to elicit hypertrophy.

In order to achieve a comprehensive accurate assessment the researchers of this study used a variety of measurable variables. $VO_2$ and respiratory exchange ratio (RER) were used to yield a measurement of aerobic energy expended while lactate measurements were taken to assess the amount of anaerobic energy expended. Rating of perceived exertion (RPE) and heart rate (HR) were also measured in this study. Our hypothesis was that HIIT would yield greater energy expenditure than SUPER training in a shorter duration of time. Measuring the energy expenditure associated with HIIT and SUPER will allow us to better understand and prescribe exercise programs for specific populations based on their overall goals.

**Statement of Purpose**

The purpose of this study is to determine and compare the energy expenditure between two different types of RT: HIIT and SUPER.

**Research Questions**

1. Which type of RT program results in the largest aerobic, anaerobic, and total energy expenditure in trained young men on average?
2. Is there a difference in average $VO_2$, RER, RPE, or HR when comparing SUPER to HIIT?

## Assumptions

1. It is assumed that $VO_2$ and RER are accurate measurements of aerobic energy expended.
2. It is assumed that lactate measurements are a valid form of assessment when measuring anaerobic energy expended.
3. It is assumed that the Polar HR Monitor is a valid instrument to measure HR.
4. It is assumed that the participants of this study will fill out the Physical Activity Readiness Questionnaire (PAR-Q) to the best of their ability.

## Limitations

1. Participants complete the exercise programs to the best of their abilities.
2. Participants will not alter their diet or hydration levels in a way that will jeopardize their workouts or the results of this study.
3. Some participants may drop out of the study for reasons out of the research group's control.

## Delimitations

1. Our research population only includes trained young men between the ages of 18-35 who have experience participating in RT twice a week for at least six months, therefore the results may not be transferrable to other sexes, age groups, or fitness levels.
2. All research participants reside in the northern Minnesota and North Dakota, therefore the results may not be transferrable to different geographical regions.
3. This study only uses a small portion of exercises that could be implemented into a RT exercise program, therefore similar studies with different exercises, different exercise volumes, or an alternate exercise order may yield different results.

## Significance of Study

This study was performed with the aspirations of increasing the knowledge of how different RT programs can influence energy expenditure in relation to the duration of time it takes to complete the work out.

## Definition of Terms

Aerobic – Exercise that requires oxygen to produce the necessary energy (ATP) to carry out the activity (Hoeger & Hoeger, 2014).

Agonist – A muscle that is shortening to perform a concentric action (Coburn & Malek, 2012).

Anaerobic – Exercise that does not require oxygen to produce the necessary energy (ATP) to carry out the activity (Hoeger & Hoeger, 2014).

Antagonist – A muscle, typically anatomically opposite the agonist, that can stop or slow down a muscle action caused by the agonist (Coburn & Malek, 2012).

Adenosine Triphosphate (ATP) – The universal energy-carrying molecule manufactured in all living cells as a means of capturing and storing energy (Coburn & Malek, 2012).

Borg Scale – A 15-grade scale measuring an individual's perception of exertion during physical work (Borg, 1982).

Calorie – The amount of heat necessary to raise the temperature of one gram of water 1 degree Celsius (Brooks, Fahey, & Baldwin, 2005); used to measure the energy value of food and cost (energy expenditure) of physical activity (Hoeger & Hoeger, 2014).

Calorimetry – A procedure to assess metabolic rate by measuring heat (Brooks et al., 2005).

Cardiorespiratory System – Made up of the lungs, heart, and blood vessels which deliver oxygen to the cells (Hoeger & Hoeger, 2014).

Circuit Resistance Training – A resistance training form which is characterized by using lighter resistances (40-60% of 1RM) and shorter rest periods between exercises (Gotshalk, Berger, & Kraemer, 2004).

Concentric Contraction – A muscle action in which the muscle is able to overcome the resistance, leading to muscle shortening (Coburn & Malek, 2012).

Eccentric Contraction – Action that occurs when a muscle cannot develop sufficient tension and is overcome by an external load, and thus progressively lengthens (Coburn & Malek, 2012).

Energy Expenditure – Energy expenditure consists of four components: the sleeping metabolic rate, the energy cost of arousal, the thermic effect of food or diet-induced energy expenditure, and the energy cost of physical activity (Westerterp, 2013).

Excess Post-Exercise Oxygen Consumption (EPOC) – The oxygen taken into the body, above the resting value, that is used to replenish the two anaerobic energy systems, also termed "oxygen debt" (Fleck & Kraemer, 1997).

Glycolysis – The process where non-oxidative energy sources in muscle are broken down from glucose and glycogen (Brooks et al., 2005).

High-Intensity Interval Training (HIIT) – An exercise protocol that involves repeatedly exercising at a high intensity for 30 seconds to several minutes, separated by 1-5 minutes of recovery with no or low intensity exercise (Shiraev & Barclay, 2012).

Hypertrophy – An increase in cross-sectional area of the muscle fiber (Coburn & Malek, 2012).

Indirect Calorimetry – The measurement of oxygen consumption (Brooks et al., 2005).

Lactate - Lactate is produced as a result of anaerobic glycolysis and is used for measuring anaerobic energy expended through indirect calorimetry (Kato, Tsukanaka, Harada, Kosaka, & Matsui, 2005; Kelleher et al., 2010).

Metabolism – the sum total of processes occurring in a living organism (Brooks et al., 2005).

Oxygen consumption – The ability to supply energy for activities lasting longer than 30 seconds (Brooks et al., 2005).

One-RM – The heaviest weight the participant is able to lift for one complete repetition (Kraft, Green, & Thompson, 2014).

Physical Activity Readiness Questionnaire (PAR-Q) – An assessment tool to initially screen apparently healthy clients who want to engage in low-intensity exercise and identify clients who require additional medical screening (Coburn & Malek, 2012).

Phosphagen System – The simplest set of chemical reactions needed to produce ATP (Coburn & Malek, 2012).

Physical Activity – Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Westerterp, 2013).

Repetition – One complete movement of an exercise (Fleck & Kraemer, 1997).

Respiratory Exchange Ratio (RER) – The ratio of $CO_2$ produced ($VCO_2$) to $O_2$ consumed ($VO_2$) (Brooks et al., 2005).

Resistance training – A form of physical activity that is designed to improve muscular fitness by exercising a muscle or a muscle group against external resistance (Esco, 2013).

Rest intervals – The time interval between two sets (Coburn & Malek, 2012).

Rating of Perceived Exertion (RPE) – A self-rating system that accounts for all of the body's responses to particular exercise intensity (Coburn & Malek, 2012).

Set – A group of repetitions that are performed consecutively (Coburn & Malek, 2012).

Superset Resistance Training (SUPER) - also known as agonist-antagonist superset training, consists of performing two consecutive exercises on opposing muscle groups while limiting the rest duration between exercises (Henry Drought, 1992; Kelleher et al., 2010).

Type I Muscle Fiber – A type of muscle fiber characterized by a slow rate of action and relaxation, high aerobic metabolic activity, and high fatigue resistance.  Also known as a slow-twitch fiber (Coburn & Malek, 2012).

Type II Muscle Fiber – A type of muscle fiber characterized by a fast rate of action and relaxation, high glycolytic metabolic activity, and low-fatigue resistance.  Also known as a fast-twitch fiber (Coburn & Malek, 2012).

$VO_2max$ – The maximum capability of an individual to consume oxygen (Brooks et al., 2005).

Volume Load – The total amount of weight lifted in a training session (sets x repetitions x weight) (Coburn & Malek, 2012).

# CHAPTER II . REVIEW OF LITERATURE

The purpose of this study is to determine and compare the energy expenditure between two different types of RT: HIIT and SUPER.

## Resistance Training

During the past two decades RT has evolved from a training mode utilized almost exclusively by athletes to one utilized by almost all exercising populations (Buitrago, Wirtz, Yue, KleinÖDer, & Mester, 2013; Robergs et al., 2007). The American College of Sports Medicine (ACSM) included RT in their recommendations for exercise training for healthy adults in 1998 (Esco, 2013). The health benefits of resistance training include improved strength, anaerobic capacity, body composition, bone density, flexibility, and physical function (Robergs et al., 2007).

Training with free weights became the most popular form of exercise during the 1990's and was one of only a few training modes that continued to increase in popularity into the 21st century (Robergs et al., 2007). Being able to exercise in any location has allowed the population freedom to choose where they would like to work out as well as what kind of work out they would like to complete. The type of RT that a person chooses to participate in revolves around the fitness goals they would like to gain or maintain as well as any limitations restricting them from completing certain types or a certain intensity of exercise. Many variables can affect the intensity, duration, and results of an exercise session. Several studies have investigated the effects of varying volume loads (VL) (Buitrago et al., 2013; Kraft et al., 2014; Thornton, Rossi, & McMillan, 2011; Uchida et al., 2009), exercise volume (Buitrago et al., 2013; Kelleher et al., 2010; Kraft et al., 2014; Thornton et al., 2011; Uchida et al., 2009; Wirtz, Wahl, Kleinöder, & Mester, 2014; Zuniga et al., 2011), contraction velocity (Mazzetti, Douglass, Yocum, & Harber, 2007; Wickwire, McLester, Green, & Crews, 2009), and rest interval (RI) length (Buitrago et al., 2013; Laurent, Vervaecke, Kutz, & Green, 2014; Meckel et al., 2011; Rahimi, Qaderi, Faraji, & Boroujerdi, 2010; Ratamess et al., 2007; Ratamess et al., 2014; Shiraev & Barclay, 2012; Slettalokken & Ronnestad, 2014; Zuniga et al., 2011) on physiological responses during and after resistance exercise. These factors determine the generated power and performed work, while simultaneously, determining the energy demands of exercise (Buitrago et al., 2013).

There are a variety of ways a person may participate in RT that will allow them to alter these variables. A few common types of RT include: traditional resistance training, circuit training, superset training (SUPER), and high-intensity interval training (HIIT). Each of these training types relate to a different desirable goal and may also be chosen due to the participant's fitness level, schedule, or because of a disability. Traditional RT involves completing a set of repetitions to failure followed by an adequate rest period before subsequent bouts of the same exercise (Kelleher et al., 2010). Circuit RT was popularized as a conditioning modality in the 1970's and 1980's. It has been characterized by using lighter resistances (40-60% of One-RM) and shorter rest periods between exercises and has also been shown to improve aerobic capacity (Gotshalk et al., 2004).

**Superset Training (SUPER)**

SUPER, also known as agonist-antagonist superset training, consists of performing two consecutive exercises on opposing muscle groups while limiting the rest duration between exercises (Kelleher et al., 2010). A great example of a SUPER exercise combination is the bench press followed by the lateral pull-down (Balsamo et al., 2012). The bench press works the chest and triceps muscles while the pull-down works the back and biceps muscles. This makes it possible to go from one exercise to the next with very little rest due to the fact the participant is exercising different muscle groups. The rest interval (RI) given between sets of SUPER, if there is one, can be adjusted for each participant based on their fitness level. Other studies have used agonist-antagonist RT protocols, calling them paired sets, comparing the total volume load (VL) completed. (Robbins, Young, & Behm, 2010; Robbins, Young, Behm, & Payne, 2010).

In one study, Robbins, Young, and Behm (2010) compared paired sets to traditional sets of bench press and bench pull. In the paired sets protocol a bench pull set was completed with a bench press set with no rest between the two. Then a four-minute rest interval was given before the next paired set until a total of three sets was completed. The traditional set protocol was completed with three sets of bench pull before the three sets of bench press, each with a two minute rest interval separating each exercise set. Both protocols had sets being performed to failure using a 4-repetition max estimate completed in a pre-test. In the study the researchers showed a larger exercise volume could be completed in an equal time, 10 minutes, when comparing the paired set protocol to the traditional set protocol. This seems to contradict what has been shown in another study by Robbins, Young, Behm, and Payne (2010) that states agonist-antagonist paired set training is arguably more fatiguing than trained modalities in which antagonist work is not performed during the rest intervals between agonist exercise sets

Energy expenditure and RPE have also been studied using SUPER and traditional protocols. One study states that SUPER is likely to produce greater metabolic energy costs than traditional training because of the reduced recovery time, which leads to greater metabolic perturbation and fatigue (Kelleher et al., 2010). SUPER has also been recently mentioned by the ACSM as one in which the strength and power of the upper body can be optimized with agonist and antagonist exercises (Balsamo et al., 2012). Balsamo et al. (2012) also found that exercise order using SUPER can affect muscle fatigue and RPE in the lower body. In their study the researchers used a SUPER protocol emphasizing exercises utilizing the quadriceps and hamstring muscles. They found that the protocol that exercised the hamstrings before the quadriceps resulted in a higher volume load but also resulted in a lower RPE score showing that more work could be done while exerting less effort. While SUPER is becoming more popular among recreational RT participants HIIT has managed to acquire its own following as well.

**High-Intensity Interval Training (HIIT)**

HIIT involves repeatedly exercising at a high intensity for 30 seconds to several minutes, separated by one to five minutes of recovery with no or low intensity cardiovascular exercise (Shiraev & Barclay, 2012). HIIT has recently been used as an alternative to traditional endurance training to alter cardiorespiratory fitness, as represented by oxygen uptake and muscle metabolism (Astorino et al., 2012). It is also one of the most frequent training methods used in anaerobic and aerobic type sports (Meckel et al., 2011). HIIT can be used with aerobic exercises, resistance weights, body weight, or in many other fashions.

The intensity of HIIT depends on the type of exercise being done, the number of repetitions, the number of sets, the length of each set, and the rest interval between sets. Increasing weight, exercise time, and/or repetitions will increase the volume and intensity of the workout. Decreasing rest time between sets will elicit the same effect. HIIT has been known to result in many positive benefits in the human body, eliciting adaptations in both oxygen-dependent and independent metabolism and is practical for many exercisers because of its minimal time commitment vs. aerobic exercise (Astorino et al., 2012).

HIIT has been shown to reduce subcutaneous fat, especially abdominal fat, as well as total body mass (Boutcher, 2011; Perry, Heigenhauser, Bonen, & Spriet, 2008; Shiraev & Barclay, 2012; Tjonna et al., 2008). In a 15 week study using bouts of cycling the high-intensity exercise group lost three kg of body fat, much of which was abdominal body fat, which was significantly more than the steady state exercise and control groups (Boutcher, 2011). HIIT also improved total body mass in a study using multiple sprinting bouts over a six-week span and was shown to be a powerful method to increase whole-body and skeletal muscle capacities to oxidize fat and carbohydrate in previously untrained individuals (Perry et al., 2008). Tjonna et al. (2008) had a sample of 32 participants who each suffered from metabolic syndrome. In their study they were able to show that intermittent exercise was a better mode than continuous exercise when comparing $VO_2$, there was also evidence that aerobic capacity was an important factor in reversing the risk factors for metabolic syndrome. HIIT has also been shown to improve $VO_2$ max and insulin sensitivity (Dunstan et al., 2002; Helgerud et al., 2007; Trapp, Chisholm, Freund, & Boutcher, 2008). Helgerud et al. (2007) was able to show that a 4x4 treadmill protocol increased $VO_2$ max when the bouts were done at 90-95% of maximum heart rate in healthy, non-smoking men. A study done on patients with Type two diabetes has shown that progressive HIIT performed three days/week for six months was safe and well tolerated by older patients with type two diabetes and was effective in improving glycemic control and muscle strength (Dunstan et al., 2002). Trapp et al. (2007) was able to show that fasting plasma insulin levels were significantly improved in women who participated in a high-intensity exercise group when compared to the steady state exercise and control groups. In the same study the researchers found that fat mass, total body composition, and cardiorespiratory fitness were most improved in the high-intensity exercise group when compared to the other two groups.

HIIT is a form of RT that can be used by any population since it is extremely adaptable. The exercises that can be performed in a HIIT program are limited only by the creativity of the individual performing them and the limitations they face which may alter intensity, exercise selection, and VL. When training athletes, a prescription of intensity is advised but is ultimately self-regulated by the individual (Slettalokken & Ronnestad, 2014). To that end, there is a continuing need to monitor the impact of variable manipulation on an individual's response during interval training (Laurent et al., 2014). Generally, exercise intensities for HIIT are in the range of 70-100% of $VO_2$ max, with short intervals using 30 seconds of exercise with 30 seconds of rest and longer intervals using three minutes of exercise with three minutes of rest. These are the two most common extremes of HIIT durations used by endurance athletes (Zuniga et al., 2011). The length of the RI depends on the goal of the individual. Short rest periods are typically recommended for RT programs designed to maximize muscle hypertrophy because short rest periods augment the growth hormone response when compared with longer rest periods (Rahimi et al., 2010). HIIT can also be a method used by athletes in the off-season. In one study a group of soccer players completed HIIT once every second week in addition to other off-season activity and it was sufficient for maintaining maximal aerobic capacity as long as the HIIT completed was close to the individual's $VO_2$ max (Slettalokken & Ronnestad, 2014).

In general, the goal of HIIT is to enhance physiological, psychological, and metabolic overload by maximizing time spent performing high-intensity exercise. During HIIT, the ability to maintain adequate overload without critical disruption of homeostasis leading to premature fatigue is controlled by either duration of interval or the duration of the recovery period (Laurent et al., 2014). When comparing all of the variables associated with HIIT one that has been shown to be crucial is the RI between sets (Astorino et al., 2012; Ratamess et al., 2007; Zuniga et al., 2011).

**Rest Intervals (RI)**

The length of RI used during resistance exercise is a variable of importance to practitioners, coaches, and fitness professionals (Ratamess et al., 2007; Ratamess et al., 2014). RT makes demands on the phosphagen, glycolytic, and mitochondrial energy systems (Robergs et al., 2007) and the length of each RI is what allows these energy systems to replenish themselves. Replenishment of the ATP-phosphocreatine system, buffering of $H^+$ from glycolytic energy metabolism, and removal of lactate occur during recovery as well (Ratamess et al., 2007).

RI length depends on the training goals, fitness level, training intensity desired, and the energy system the individual would like to utilize (Ratamess et al., 2007). Someone who may not be at a high fitness level will require a longer RI than someone who is well conditioned. There have been multiple studies done comparing RI (Buitrago et al., 2013; Laurent et al., 2014; Meckel et al., 2011; Rahimi et al., 2010; Ratamess et al., 2007; Ratamess et al., 2014; Slettalokken & Ronnestad, 2014; Zuniga et al., 2011) but only a few of which used resistance training.

The intensity level of aerobic training depends on the cycling or running distance, speed, the number of repetitions, and the RI between sets (Meckel et al., 2011). Reducing RI between RT sets can adjust the demand of aerobic energy being utilized, therefore altering the results of the RT exercise program (Kraft et al., 2014; Meckel et al., 2011; Rahimi et al., 2010; Ratamess et al., 2007; Zuniga et al., 2011). Altering RI time for RT programs can maximize muscle hypertrophy (Meckel et al., 2011; Rahimi et al., 2010; Ratamess et al., 2014), hormonal responses (Meckel et al., 2011; Rahimi et al., 2010; Zuniga et al., 2011), and fatigue rate (Kraft et al., 2014; Ratamess et al., 2007; Zuniga et al., 2011). In a study by Ratamess et al. (2014) the squat and bench press were used with either one, two, or three minute RIs between each set. The results of the study show that squat repetition and performance was greatest when two and three minute RIs were used, whereas bench press repetitions were highest with three-minute RIs. These exercises were done with 75% of the one-repetition max (One-RM) that was determined prior to the exercise protocol.

Results from one study show that the optimal work-to-rest ratio is 2:1, as it elicits an optimal training intensity with little benefit gained by affording extra recovery time (Laurent et al., 2014). This means that for every 30 second set of HIIT participants completed they would get a 15 second RI. This ratio has been shown to yield an appropriate training stimulus and is perceived as less difficult (Laurent et al., 2014). When completing SUPER, the participants will get a 60 second RI since this length of time has been shown to be customary when completing SUPER training (Kelleher et al., 2010).

**Volume Load (VL)**

Along with the RI there is a crucial component to RT that cannot be overlooked when constructing an exercise program, this component is called volume (VL). The correct VL matched up with an appropriate RI can help the participant achieve maximum results from their work out. Determining VL can be difficult due to the many ways of calculating its variables. Several methods have been used to determine the volume of an exercise program in the current literature. VL can be determined by "sets x repetitions x external load" (McBride et al., 2009; Uchida et al., 2009). Other methods include maximum dynamic strength volume load (repetitions x [body mass – shank mass + external load]), time under tension (the amount of time in milliseconds in the eccentric and concentric phases of an exercise), and total work (eccentric + concentric work) for each repetition (McBride et al., 2009). Comparison of the different methods of volume can determine differences associated with hypertrophy, strength, and power protocols that can yield different results.

RT using heavy loads, low repetitions, and a moderate-to-high number of sets are typically performed to maximize strength gains (Uchida et al., 2009). However, moderate to heavy loads with moderate-to-high repetitions and multiple sets per exercise are characteristics of muscle hypertrophy training as well (Uchida et al., 2009). There are phrases such as "high reps, low weight" to define lean mass and lose weight or "high weight, low reps" to achieve hypertrophy and gain weight. Buitrago et al. (2013) completed a study that showed traditional VL designs for strength endurance, hypertrophy, and maximal strength based on this theory.

Buitrago et al. (2013) conducted a study measuring the eccentric and contraction times with different One-RM resistance. They found that the power produced is the main criterion in determining the intensity of an exercise. Another study measured similar VL on the bench press where the researchers adjusted the One-RM percentage, the amount of repetitions, and the number of sets and found that all of the participants elicited similar hormone responses no matter what program they participated in (Uchida et al., 2009). Uchida et al. showed that no matter what the fitness level of the participant exercising, a VL can be set up at a lighter or heavier resistance and can elicit similar energy expenditure and hormone function. Thornton et al. (2011) backed this up by using a variable load program utilizing a high repetition to low weight protocol vs. a high weight to low repetition protocol where each yielded similar results in energy expenditure. When comparing contraction times research has shown that slow contraction may yield more fatigue but will not amount to a greater amount of energy expended (Mazzetti et al., 2007). Super-slow resistance training was compared to traditional machine protocols, which resulted in more repetitions completed during the machine protocol due to fatigue (Wickwire et al., 2009).

To conclude, when putting an exercise program together VL should be emphasized to achieve maximum results. Contraction time may play a part in each repetition completed, but it should not be the emphasis of the work out. RI (Buitrago et al., 2013; Laurent et al., 2014; Meckel et al., 2011; Rahimi et al., 2010; Ratamess et al., 2007; Ratamess et al., 2014; Shiraev & Barclay, 2012; Slettalokken & Ronnestad, 2014; Zuniga et al., 2011) and VL (Buitrago et al., 2013; Kelleher et al., 2010; Kraft et al., 2014; Thornton et al., 2011; Uchida et al., 2009; Wirtz et al., 2014; Zuniga et al., 2011) have been shown to factor largely into completing a quality work out based on the participant's fitness level while achieving maximum results.

**Energy Expenditure**

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Westerterp, 2013). Body movement requires energy as produced by muscles (Westerterp, 2013). The accepted criteria to validate techniques of estimating physical activity is calorimetry (Westerterp, 2013). Westerterp (2013) described total energy expenditure consisting of four components: the sleeping metabolic rate, the energy cost of arousal, the thermic effect of food or diet-induced energy expenditure, and the energy cost of physical activity. Further, there are a number of non-calorimetric techniques for the assessment of physical activity, such as diaries, questionnaires and interviews. Lastly, they discuss the different variables that can affect energy expenditure such as height, weight, body composition, gender, and levels of physical activity. Aerobic and RT have both been shown to expend energy (Hunter et al., 2012), although one study shows that the energy cost of moderate duration and intensity aerobic exercise exceeds that of RT when the two modes are matched for total time and relative intensity (Bloomer, 2005).

Although non-calorimetric techniques can be used to assess energy expenditure they can be inaccurate and deceiving for a variety of reasons. In multiple studies $VO_2$ measurements (Astorino et al., 2012; Buitrago et al., 2013; Gotshalk et al., 2004; Kelleher et al., 2010; Mazzetti et al., 2007; Ratamess et al., 2007; Ratamess et al., 2014; Robergs et al., 2007; Scott, Leary, & TenBraak, 2010; Thomas, Larson, Hollander, & Kraemer, 2014; Thornton et al., 2011; Vilaça, Bottaro, & Santos, 2011; Zuniga et al., 2011) and lactate measurements (Gotshalk et al., 2004; Kato et al., 2005; Kelleher et al., 2010; Laurent et al., 2014; Mazzetti et al., 2007; Meckel et al., 2011; Ratamess et al., 2007; Wirtz et al., 2014; Zuniga et al., 2011) have been shown to be accurate assessments of aerobic and anaerobic energy expenditure. Studies have also shown that $VO_2$ can be easily converted into calories expended using an RER of 1.0 and the associated caloric equivalent of 5.05 $kcal/L^{-1}$ (Peterson, Palmer, & Laubach, 2004; Ratamess et al., 2014; Robergs et al., 2007).

Measures of lactate can be converted to oxygen equivalent values as 3 ml $O_2/kg^{-1}$ body weight per millimole of blood lactate and then converted to kilojoules as 21.1 kJ per liter of $O_2$ which in turn can give us an accurate measurement of anaerobic energy expenditure (Scott, 2006). When $VO_2$ and lactate calculations are combined an accurate measurement of aerobic, anaerobic, and total energy expended can be formed. Some studies say that faster rates of energy expenditure are seen in explosive exercises over slower contraction exercises (Buitrago et al., 2013; Mazzetti et al., 2007) while others express the importance of RI length (Buitrago et al., 2013; Laurent et al., 2014; Meckel et al., 2011; Rahimi et al., 2010; Ratamess et al., 2007;

Ratamess et al., 2014; Slettalokken & Ronnestad, 2014) and VL (Buitrago et al., 2013; McBride et al., 2009; Scott et al., 2010; Uchida et al., 2009; Wickwire et al., 2009) on energy expended.

**Oxygen Consumption ($VO_2$)**

$VO_2$ is one form of indirect calorimetry and has been used as a measurement tool for a variety of studies with the goal of measuring aerobic energy expenditure (Astorino et al., 2012; Buitrago et al., 2013; Gotshalk et al., 2004; Kelleher et al., 2010; Mazzetti et al., 2007; Ratamess et al., 2007; Ratamess et al., 2014; Robergs et al., 2007; Scott, 2012; Scott et al., 2010; Thomas et al., 2014; Thornton et al., 2011; Vilaça et al., 2011; Zuniga et al., 2011). While some studies analyzed $VO_2$ to measure aerobic energy expenditure using traditional aerobic exercises (Astorino et al., 2012; Thomas et al., 2014; Zuniga et al., 2011) or the combination of aerobic exercise and RT (Vilaça et al., 2011), other studies used $VO_2$ as a measure of aerobic energy expenditure through the use of RT alone (Buitrago et al., 2013; Gotshalk et al., 2004; Kelleher et al., 2010; Mazzetti et al., 2007; Ratamess et al., 2007; Ratamess et al., 2014; Robergs et al., 2007; Scott, 2012; Scott et al., 2010; Thornton et al., 2011).

Some studies that analyzed $VO_2$ through traditional aerobic exercises, such as walking and cycling, also determined $VO_2$max. Zuniga et al. (2011) used a Monark cycle ergometer to measure $VO_2$max by setting the cycle to 80 watts (W), a relatively low resistance, increasing resistance 40 W every two minutes until 160 W was reached. At this point resistance was increased 20 W every minute until exhaustion. $VO_2$max was defined as the highest $VO_2$ value in the last 30 seconds of the test if the subject met at least two of the criteria set for assessment including HR, RER and oxygen plateau. Similarly, a test completed by Astorino et al. (2012) used the Wingate test to measure $VO_2$max. The Wingate test also uses a cycle ergometer and has the participant increase to peak speed with no resistance before administering the load, which is

7.5% of the participant's body weight, to the cycling resistance (Astorino et al., 2012). At this point the participant cycles as hard as they can for 30 seconds after which the test is stopped and they have a 5 minute recovery period. Thomas et al. (Thomas et al., 2014) completed a study which compared a two-hand kettlebell exercise program to graded treadmill walking. The authors of the paper confirmed their hypothesis that the moderately intense kettlebell protocol produced metabolic responses similar to those produced by a brisk walking protocol when analyzing $VO_2$ and RER. These studies show that $VO_2$ and $VO_2max$ can be measured using a variety of different protocols as well as the fact that RT and aerobic training can elicit similar responses.

Although measuring different exercise protocols separately is of importance to understanding how different programs affect $VO_2$, combining RT and aerobic training is also a topic of interest when discussing $VO_2$. Vilaca et al. (2011) completed a study that showed the sequence of exercises, aerobic training before RT and vice versa, did not interfere with energy expenditure during the training session. They went on to conclude that neither intermittent nor continuous exercise altered $VO_2$. These studies are of importance to show that $VO_2$ can be used to measure energy expenditure using traditional aerobic exercise with the inclusion of RT exercises.

HIIT and SUPER are only concerned with the effect different types of RT programs have on $VO_2$ since no traditional aerobic exercises are used. Most RT investigations combine multiple intermittent lifting periods with rest/recovery periods between sets to portray a single rate-function measurement for the entire workout (Scott, 2012; Scott et al., 2010). Bench press is generally one of the most common RT exercises performed. The bench press has been studied in the past in relation to $VO_2$ in a variety of different RT programs. Some of these studies measured bench press alone (Buitrago et al., 2013; Ratamess et al., 2007; Ratamess et al., 2014; Scott, 2012; Scott et al., 2010) while others analyzed the bench press in combination with other RT exercises (Kelleher et al., 2010; Robergs et al., 2007).

As previously stated, many variables can be adjusted in an exercise program, but when broken down each specific exercise can be adjusted as well. Contraction time, eccentric time, RI between sets, and VL are just a few of the adjustments that can be made to exercises and exercise programs. Each of these variables can have an effect on the amount of energy expended when completing the exercise. When measuring contraction time in comparison to $VO_2$, Buitrago et al. (2013) found that RT methods with the lowest load and highest movement velocity elicit the highest response in mean $VO_2$. The same authors also state that the slower $VO_2$ kinetics of type 2 fibers (when compared with type 1 fibers) result in a lower mean $VO_2$ while exercising with increasing external load.

It is also well established that RI will have a large effect on $VO_2$ as we have previously stated. The longer the RI given between sets the more time the body has to replenish its energy systems (Ratamess et al., 2007; Ratamess et al., 2014). One thing to note is that recovery ability could augment other modalities of anaerobic exercising including resistance training. Thus, it is likely that endurance-trained individuals may have a greater capacity to maintain resistance exercise performance when short RIs are used compared to individuals with moderate or poor aerobic fitness (Ratamess et al., 2014).

When combining RT exercises it is important to use the same exercise order to minimize error when assessing energy expenditure due to fatigued muscles of the participant and not necessarily depletion of energy. SUPER and circuit RT programs include multiple exercises built into a single program and can maximize cardiovascular demands on the body. When combining different RT exercises the cardiovascular system can continue to work while a muscle or muscle group can be rested. Robergs et al. (2007) conducted a study combining the bench press and parallel squat in order to evaluate $VO_2$. Their study shows that 5-23% of One-RM bench press was heavy enough to induce $VO_2$ values above resting while light enough to be performed for five consecutive minutes. Likewise, 31-57% of 1 RM parallel squat was heavy enough to induce $VO_2$ values above resting while light enough to be performed for five consecutive minutes.

A high volume load is not needed to affect $VO_2$. Also, lower weight and higher repetition programs may have a greater effect on $VO_2$ than higher weight and lower repetition programs. Resistance training makes demands on the phosphagen, glycolytic, and mitochondrial energy systems. Robergs et al. (2007) claims it is impossible to completely measure the metabolic cost of RT by applying indirect calorimetry during moderate- to high-intensity RT as that method ignores the contributions of the phosphagen and glycolytic energy systems. Although $VO_2$ measurements do not analyze the phosphagen or glycolytic energy systems one other indirect calorimetry method does, lactate testing.

**Lactate**

One method that measures anaerobic energy expended is blood lactate evaluation. Lactate is produced as a result of anaerobic glycolysis and is a valid instrument for measuring anaerobic energy expended (Kato et al., 2005; Kelleher et al., 2010; Mazzetti et al., 2007). Intensive exercise like RT increases blood lactate concentration and lactate is commonly used to define the metabolic stress of an exercise and depends on the lactate production, transportation, metabolism, and elimination (Wirtz et al., 2014). The benefits of interval training are well documented and include allowance of a greater volume of high-intensity exercise and enhancement of lactate kinetics (Zuniga et al., 2011). The effects of SUPER on lactate are also documented (Kelleher et al., 2010). Since lactate is a valid measurement of anaerobic energy expended in HIIT and SUPER it can be used to measure an overall value of energy expended during exercise.

Multiple studies have compared the effects of RI in exercise programs on lactate (Kelleher et al., 2010; Meckel et al., 2011; Ratamess et al., 2007; Zuniga et al., 2011). Meckel et al. found that when comparing sprint intervals on a treadmill, a shorter sprint interval resulted in higher lactate concentrations vs. a longer sprint interval even though the RI lengths were the same. This may have been because the intensity of the running interval depended on speed and repetitions, and while repetitions were equal, speed may not have been due to the distance of the intervals (100m, 200m, 300m, and 400m). In contrast, Zuniga et al. (2011) completed a study comparing 30 second intervals and three minute intervals on a cycle ergometer. They found that the three minute intervals actually lead to higher blood lactate concentrations than the 30 second intervals. This difference may be due to the different modes of exercise used in the studies (Meckel et al., 2011; Zuniga et al., 2011). Laurent et al. (2014) used a HIIT program of six four-minute intervals on the treadmill at maximal effort separated by either a one, two, or four minute recovery to compare the ratio of work to rest. The study found that a 2:1 work to rest ratio worked best in yielding the appropriate training stimulus. They also found that there was no difference between men and women when comparing lactate levels using 1 minute RI, but the women had a lower lactate measurement at the 2 minute RI and a higher level at the 4 minute recovery.

Lactate differences are also of interest when comparing RT programs since many times RT is more focused on anaerobic energy expended than aerobic energy expended. RT programs use a variety of muscle groups and the amount of lactate produced can be a result of the muscle groups used. Gotshalk et al. (2004) found that lactate concentrations associated with small muscle groups are higher than those associated with larger muscle groups at the same $VO_2$. When comparing bicycling and running at the same relative $VO_2$, researchers found higher lactate concentrations in a bicycle protocol than the treadmill protocol even though the cycling protocol required less muscle mass (Ekblom, Astrand, Saltin, Stenberg, & Wallström, 1968).

Ratamess et al. (2007) used RT to compare the effect of different RI on the bench press. In this study 75% One-RM and 85% One-RM were used with a randomization of RI between the five sessions. The researchers found no difference between RI and lactate. Another study showed differences in lactate when comparing traditional exercise programs to SUPER exercise programs. Kelleher et al. (2010) found that less recovery during SUPER is likely to be the reason blood lactate concentrations were greater when compared to a traditional RT program since there is less time when energy production is low enough for aerobic metabolism alone to meet energy demand.

Not unlike a HIIT vs. SUPER comparison, Mazzetti et al. (2007) compared slow squats, explosive squats, and heavy explosive squats by changing the contraction times of each. The weight and number of sets for the first two were similar but was changed for the heavy explosive squats, although the repetitions were decreased for each set. Blood lactate measurements were greater after slow contraction squats when compared to explosive squats, but the energy expenditure was higher in the explosive squats which may have been a result of the contraction speed. These results support the argument that contraction time can increase some component of workout intensity. It has also been shown that lactate may drop during the actual exercise portion of the testing but will be elevated during recovery (Wirtz et al., 2014). Given a sufficiently high intensity and volume of weight training, rapid substrate-level ATP turnover with lactate production can make a significant contribution to total energy expenditure (Scott, 2006). It is important to note that excess post-exercise oxygen (EPOC) has also been used to measure energy expenditure, but due to the potential problems associated with the valid measurement and interpretation of anaerobic energy expenditure, researchers often have taken to omitting either the anaerobic energy expenditure component or the EPOC measurements (Scott, 2006).

**Respiratory Exchange Ratio (RER)**

RER is a measure of gas exchange expressed as a ratio of $CO_2$ produced ($VCO_2$) to $O_2$ consumed ($VO_2$) (Brooks et al., 2005). During hard exercise, an individual's RER approaches 1.0, whereas during prolonged exercise, the RER may be somewhat lower (Brooks et al., 2005). The ratio given can correspond to the type of energy being expended. For example, in faster runners more carbohydrates may be used through the glycolysis cycle, but in slower runners the ratio may be lower indicating less carbohydrate use and more lipid use. Converting a 30 second averaged RER along with an absolute oxygen consumption value can give the amount of aerobic energy per minute expended in the form of calories consumed (Peterson et al., 2004). A RER of 1.00 usually shows the use of carbohydrates for energy while 0.70 equates to fat, and 0.80 to protein (Brooks et al., 2005).

Although RER is commonly used for aerobic exercise, it can be used during RT to help define the type of aerobic energy being used. In a study measuring the metabolic responses to different RI on the bench press Ratamess et al. (2007) found that RER was significantly elevated during longer RI (two minute, three minute, five minute) when compared to a short 30 second RI. This could be due to the high anaerobic nature of each set that resulted in high levels of $CO_2$

which in turn resulted in in high RER values. Similarly, in a study comparing moderate-duration RT (squatting, which would use more anaerobic energy) and aerobic exercise (cycling) total calories expended and total work done was greater during cycling, but RER was greater during the squatting exercise (Bloomer, 2005). Thomas et al. (2014) compared kettlebell exercise and graded treadmill walking and found the RER for each to be similar. If the intensity or resistance were too high the participants would have fatigued much faster due to increased volume loads that could not be sustained for a long period of time. (Kraemer & Ratamess, 2004).

RER can also be helpful when comparing two RT protocols to each other to measure energy expenditure (Ratamess et al., 2014; Robergs et al., 2007; Scott, 2006; Thornton et al., 2011). When comparing bench press to squat using the same VL (5x10 at 75% 1RM) Ratamess et al. found that RER was significantly higher during the bench press exercise than the squat exercise. When using different volume loads, such as in the study by Thornton et al. (2011), RER was not significantly different in the 3x15 at 45% 1RM when compared to the 3x8 at 85% 1RM exercise protocol. In the study by Thornton et al. a RER greater than 1.0 during exercise was expected to be all carbohydrate substrate expenditure. In the way different VLs and exercise protocols can elicit different RER effects, other variables can be affected as well. One of these variables is called rating of perceived exertion (RPE) and it has been used in multiple exercise studies.

**Rating of Perceived Exertion (RPE)**

Health professionals evaluating exercise programs have always needed a way to assess effort during exercise. While there are a variety of ways to do this, one way that has been time-tested and used in a variety of different settings is the 15-grade Borg Scale (Brooks et al., 2005; Kraft et al., 2014; Laurent et al., 2014; Meckel et al., 2011; Meir, Guang-Gao, Shi, Beavers, &

Davie, 2014; Slettalokken & Ronnestad, 2014; Thornton et al., 2011; Wickwire et al., 2009; Zuniga et al., 2011). The OMNI scale (Balsamo et al., 2012) is another method that has been used in adults, but the Borg scale has been well established in interval training studies (Laurent et al., 2014; Meckel et al., 2011; Meir et al., 2014; Slettalokken & Ronnestad, 2014; Zuniga et al., 2011). The 15-grade Borg Scale is set up on a ranking of six to twenty, with six being the least exertion (e.g. reading a book) and 20 being maximal exertion (e.g. the last kick before failure).

RPE using the Borg Scale has been used in exercise programs focused on interval training (Laurent et al., 2014; Meckel et al., 2011; Meir et al., 2014; Slettalokken & Ronnestad, 2014; Zuniga et al., 2011) and general RT (Kraft et al., 2014; Thomas et al., 2014; Thornton et al., 2011; Wickwire et al., 2009). Using RPE for interval training has opened our eyes as to how various RIs can affect difficulty. Slettalokken et al. (2014) found that soccer players participating in an interval session focusing on the shuttle run each week or every second week exhibit different RPE. The group who completed the shuttle run every second week had a Borg score that averaged 0.7 points lower after the HIIT session than the group that had the session every week. This study shows that the participants felt the shuttle run required less effort when completed every second week rather than every week. Zuniga et al. (2011) completed a study using four different protocols, two at 90% maximum power output and two at 100% maximum power output, on a cycle ergometer with either a 30 second exercise interval followed by a 30 second rest period or a three-minute exercise interval followed by a three-minute rest period. The study showed no significant difference across the different protocols as the mean for each was a rating between 14 and 15 on the Borg Scale. Meir et al. also completed a study with intervals using the shuttle run as their mode of exercise measuring physiological measures of wearing a nose clip compared to not wearing a nose clip. The four protocols used were 1x40 meters, 1x80 meters, 1x120 meters, and 1x160 meters. Each protocol was completed once without a nose clip and once with a nose clip. In the study the researchers found that there were no resulting significant differences between the physiological measures for the shuttle runs wearing the nose clip to those not wearing it.

When measuring RPE using cycle ergometer interval training there was no difference found between tested groups who used the 30-second exercise to 30-second rest protocol and the 3-minute exercise to 3-minute rest protocol (Zuniga et al., 2011). Meckel et al. (2011) showed decreasing distance IT was associated with a greater metabolic and anabolic response but these responses were not accompanied by an increase in RPE. The findings of this study imply that physiologic and psychological responses to IT do not necessarily correlate. Another study completed by Laurent et al. (2014) focused on the RPE of men vs. women during IT and found that there are meaningful sex differences in perceptual strain both during and after self-paced HIIT as evidenced by RPE.

When comparing an aerobic exercise, incline treadmill walking, to a RT exercise, kettlebell swings, using identical intervals, that included three continuous sets of 10-minute intervals of exercise with three minutes of rest between each set, Thomas et al. (2014) found that RPE for the kettlebell protocol was greater when compared to treadmill walking at the same $VO_2$. Thornton et al. (2011) studied the difference in RPE between a high weight/low repetition RT protocol and a low weight/high repetition RT protocol using the same exercises. To their surprise RPE was similar in both sessions. Contraction time in an exercise has been shown to alter RPE as shown in a study done by Wickwire et al. (2009). When analyzing the difference between RT using super slow contractions and a traditional protocol on RT machines their research showed traditional machine training brought about a higher RPE on average than the super slow contraction protocol. Lastly, in a study done by Kraft et al. (2014), six different RT exercises were implemented into a program and RPE was evaluated between 4 protocols that alternated VL and RI variables. Post-set RPE was shown to be higher when the protocol consisted of more repetitions and more recovery time, but no other significant differences were found between pre- and post-set RPE.

It is important to add that many research studies that measure how exercise effects different physiological and psychological variables use a nose plug while administering the exercise testing to accurately measure $VO_2$. A study by Meir et al. (2014) has shown that the acute effect of mouth only breathing on HR, RPE, blood lactate, and ventilatory measures during HIIT resulted in no statistically significant effects on pulmonary ventilation, HR, RPE, blood lactate, or the total time to complete the exercise of interest (in this case, the shuttle run). This study is of importance because something as small as HR can have an effect on many other variables being measured.

## Heart Rate (HR)

Heart rate is an easy yet useful tool in measuring the efficacy of an exercise program. A few ways to take an accurate HR reading include: taking the pulse of an individual, listening to their chest through a stethoscope, or utilizing a HR monitor to show the HR on a continuous basis. It has been well documented that HR will increase with exercise (Astorino et al., 2012; Bloomer, 2005; Gotshalk et al., 2004; Hunter et al., 2012; Kato et al., 2005; Kraft et al., 2014; Meir et al., 2014; Ratamess et al., 2007; Ratamess et al., 2014; Thomas et al., 2014; Thornton et al., 2011; Wickwire et al., 2009; Zuniga et al., 2011) but how specific variables, such as RI and

VL, in exercise studies affect heart rate as well as how heart rate affects these other variables will be discussed below.

When comparing different interval lengths on the Monark cycle ergometer Zuniga et al. (2011) found that the average HR of the 30-second intervals was slightly higher than the 3-minute intervals in the participants, but the blood lactate content was actually lower on average in the shorter intervals. Astorino et al. (2012) also used a cycle ergometer to conduct six sessions of Wingate testing over a two week span. Their study shows no significant difference between baseline max HR and post-HIIT max HR. Ratamess et al. (2007) compared different rest intervals with different volume loads (5x10 at 75% One-RM and 5x5 at 85% One-RM) on the bench press and found that while HR was elevated post-exercise blood lactate was not. The same study also found that HR tended to increase with the completion of each set in both RT protocols.

One reason many people decide to participate in an exercise regimen is to lose weight. It has been shown that both aerobic training and RT have an effect on maintaining weight loss and decreasing HR during rest and exercise (Hunter et al., 2012). Circuit RT programs combine RT with aerobic exercise. The physiological stress of a circuit RT program has been shown to sustain a HR of more than 70% of maximum HR (Gotshalk et al., 2004). In a study of overweight African-American women (BMI 25-29.9) two different training intensities were used and the higher intensity workout elicited effects of a significantly elevated HR above baseline whereas the lower intensity workout did not (Thornton et al., 2011).

When using a RT program with six different RT exercises and two different RI, Kraft et al. (2014) has shown that the shorter rest interval of 90 seconds had a faster pre-set HR than the 3-minute interval. No other significant pre-set or post-set HR differences were observed. When comparing the order of exercises between the squat and bench press using identical sets, repetitions, and One-RM percentage for each, Ratamess et al. (2014) found that when the squat exercise was completed HR was elevated for each of the three different RI but didn't have any correlation to blood lactate levels. This study also showed that when using one, two, and three minute RI, the shorter the RI the higher the average HR was for the exercise session. One study has shown that HR response to squatting at 70% of One-RM and cycling at 70% of $VO_2$max for an equal amount of time results in an almost identical HR response, even though the RPE was greater during squatting (Bloomer, 2005). In a similar study that compared incline treadmill walking to RT using a kettlebell HR remained higher during kettlebell exercise even though the HR response to both exercise protocols was similar (Thomas et al., 2014).

Contraction time can also play a part in HR response. As stated previously RPE has been shown to be higher in traditional RT when compared to super-slow RT using resistance machines. The same can be said for HR, since HR is higher during traditional RT in comparison to super-slow RT (Mazzetti et al., 2007). So while HR is an easy variable to measure, it is an important instrument when assessing an exercise program.

To conclude, HIIT and SUPER are two different types of resistance training used by the exercise population. While their protocols may be different due to the goals of the individuals performing them, the overall goal of RT is to gain or maintain fitness levels. To do this VL and RI may be altered. The VL and RI will have an effect on the energy expended, measured by $VO_2$, lactate, and RER and possibly on the RPE and HR as well. The research shown above allows us to see how each variable can be independent as well as how each variable may affect one another.

# CHAPTER III. METHODS

The purpose of this study is to measure the difference in energy expenditure when comparing a HIIT to a SUPER exercise protocol in trained young men.

## Research Questions

1. Which type of RT program elicits the most energy expenditure in trained young men on average?
2. Is there a difference in average $VO_2$, RER, RPE, or HR when comparing SUPER to HIIT?

## Population

When using G*power 3® (Faul, Erdfelder, Lang, & Buchner, 2007) software to assess the number of participants needed for this study based on effect size, measurements taken, and power value, we were repeatedly given a number between 6-12 participants. In a study measuring the effect of SUPER on $VO_2$ and lactate in recreationally active men Kelleher et al. (2010) had a population size of ten. In a study conducted by Zuniga et al. (2011) where $VO_{2,}$ lactate, RPE, and HR were compared using different HIIT protocols a sample size of 12 participants was used. Therefore, for this study we used 12 men RT men (23.91 ± 3.58 years; 180.87 ± 6.24 cm; 86.86 ± 5.05 kg) to ensure adequate results.

Each participant was a volunteer and chose to participate knowing the procedures and risks of being in the study. At the time of data collection each participant was injury free and had at least six months of resistance training experience exercising a minimum of twice per week immediately prior to the study. Each participant filled out a PAR-Q form to determine their eligibility for the study. They each also had to sign an informed consent form acknowledging the risks of participating in exercise while agreeing to follow all instructions given to them. The study was approved by the university's Institutional Review Board. All participants were volunteers and could remove themselves from the study at any time if they chose to. They were also informed that if at any time an injury were to occur they were to inform us and remove themselves from the study immediately.

## Instrumentation

Many forms of instrumentation were used for the study since there were multiple variables being measured. We utilized PAR-Q forms to acquire age and exercise experience of each individual to determine if they were eligible for the study. A Detecto Eye-Level Scale (Detecto, Webb City, MO) was used to record the weight and a Seca Stadiometer (Seca, Chino, CA) was used to obtain the height of each participant. A metabolic cart (Medgraphics, St. Paul, MN) with a mouthpiece was used to obtain aerobic energy expenditure measurements by analyzing $VO_2$, the machine also calculated the amount of total Kcals expended aerobically. The metabolic cart allowed us to see the amount of oxygen being utilized by the body during rest as well as how it changed throughout each exercise protocol. Lastly, the metabolic cart allowed us to obtain the respiratory exchange ratio (RER) by calculating the ratio of $CO_2$ produced to $O_2$ consumed. A lactate tester and lactate strips (Lactate Plus, Hawthorne, NY) were used to measure anaerobic energy expenditure by means of a blood draw. The blood was drawn using a B-D Lancet 100 (Sports Resource Group Inc., Hawthorne, NY) to administer a finger prick to each participant. A blood sample was taken from the finger using the lactate tester and strips that gave us a measure of lactate in the blood. A Polar heart rate monitor chest strap and watch (Heart Rate Monitors USA, Warminster, PA) were used to view each participant's heart rate at rest and throughout their exercise sessions. RPE was measured using the Borg's Rating of Perceived Exertion 15-Grade Scale which was printed on a piece of paper so the participant could point out there perceived exertion level throughout each exercise session. A custom form was created and completed using the variables analyzed from each individual's pre-test, resting, and exercise protocol results.

The resistance training was completed using a standard 45 lb. Olympic barbell and weight plates ranging from 2.5 lbs. to 45 lbs. for the bench press and upright row. For the bicep curl and triceps extension these same plates were used but instead were loaded onto a 15 lb. barbell. For all exercises using free weights, clips were used to ensure the weights would not shift or fall off the bar. For the leg extensions and leg curls a Cybex (Cybex International, Owatonna, MN) weight stack machine with handles and an adjustable seat was utilized.

**Procedures**

After completing the PAR-Q and informed consent forms, measurements of height and weight were taken. One-RM testing was then performed. After One-RM testing was completed a minimum of 72 hours was given before the HIIT exercise protocol session was administered. Since this study required a VL that was equal for both protocols, HIIT was always performed during the first session so that the VL could be calculated. After the HIIT VL was calculated we could determine the number of repetitions that needed to be performed for each exercise for the SUPER protocol. After the HIIT exercise session was complete at least 72 hours was given before each participant completed the SUPER exercise protocol portion of the study. At this point all data was gathered and analyzed to establish the results of the study.

Participants were not to eat within three hours of One-RM testing, were not to smoke, consume alcohol, caffeine, creatine, energy drinks, pre-workout supplements, or other ergogenic aids within 12 hours of testing, and were to avoid resistance training for 48 hours before each testing session. They were also instructed to be hydrated to avoid dehydration during the workout and not to drastically alter their diet throughout the study.

**One-Repetition Maximum Measurements**

A certified personal trainer ensured all subjects adhered to proper technique during their testing session. Safety during One-RM testing was achieved by continuous supervision and correct spotting methods for each exercise performed. After a warm-up, initial One-RM attempt values were 90% of self-estimated One-RM. Each subject attempted progressively heavier weights until they could not complete 1 repetition with correct form on their own. A minimum of 2 minutes of rest was given between attempts with the last successful attempt being recorded as the participant's One-RM for each exercise. The One-RM was utilized as a means for standardizing the percentage of weight lifted by each subject during the next phase of the testing protocol.

The exercises performed in this study were the bench press, bent-over row, bicep curl, lying triceps extension, leg extension, and lying leg curl, in that order. The order was established by placing compound exercises before isolation exercises and all upper body exercises before lower body exercises to prevent pooling of blood in the legs (Kelleher et al., 2010). The lab used for the One-RM testing and exercise protocols had weighted plates ranging from 2.5 lbs. up to 45 lbs. for each of the free weight resistance training exercises. All One-RM testing was completed on the same day and at least 72 hours before the start of the HIIT exercise protocol session.

The bench press utilized these plates along with a traditional bench and 45 lb. barbell. The bench press technique required participants to use a pronated grip and to remain in a 5-point contact zone which consisted of both feet, the buttocks, shoulder blades, and back of the head to be in contact with either the bench or ground at all times. A lift was deemed successful if the subject was able to lower the bar eccentrically in a controlled manner, lightly touch the chest, and return the bar concentrically to a fully locked out position without assistance from spotters (Robergs et al., 2007).

The bent-over row was completed using a 45 lb. barbell on the ground as well as the free weight plates available in the lab. Each participant was to stand over the bar, grab the bar with a slightly wider than shoulder width pronated grip, bend the knees, and bend over at the waist keeping the back straight and head up. One-RM was established when the participant could bring the bar up to the inferior portion of their chest, being careful not to shift their weight, and then lower it back down safely without dropping it.

The One-RM bicep curl was completed using a 15 lb. bar along with the plates available in the lab. For successful completion of a bicep curl the participant had to stand straight up with good posture keeping their head up, holding on to the bar using a supine grip roughly shoulder width apart. For a successful One-RM attempt they would need to concentrically curl the bar up to their chest and eccentrically lower it back down without shifting weight excessively or losing form.

The One-RM lying triceps extension was completed on an adjustable flat bench using the same 15 lb. bar and free weights as used for the curl. The participant was lying down on the bench with the same 5-point contact zone established for the bench press. They were to grip the bar with a pronated grip, like used on the bench press, and slowly lower the bar down towards their face bending only their elbows and then extend the bar back up to the starting position. Successful completion of one repetition using the correct form maintaining the 5-point contact zone resulted in the participant's One-RM.

The Cybex multi-stack machine was used for the leg extension One-RM test. The participant was seated with their hands placed on the handles on each side of the seat with the lower portion of the shins of their legs pushing against the leg pads. For a successful One-RM attempt the participant needed to keep their back against the back pad, hands on the handles, and push the weight from the original position, knees at 90 degrees, up to the point where their legs were straight. At this point they could lower the weight back down carefully, without dropping the weight stack, into the starting position where the knees were back at 90 degrees.

To establish a One-RM for the lying leg curl the participant was lying face down with their legs straight back. Each participant started with their legs straight, stomach against the horizontal pad, and hands on the handles under the face pad. In order for the One-RM to be established the participant needed to contract their hamstrings by bending their knees, pulling the weight towards their buttocks, until their knees were at 90 degrees, and then guide the weight back down by straightening their legs in a controlled manner while not dropping the weight stack. After all One-RM measurements were completed the weight being used for each exercise protocol was calculated using the One-RM achieved for each individual exercise.

**High-Intensity Interval Resistance Training Protocol**

The exercise protocols were to be completed at least 72 hours apart with the same restrictions for the participants regarding intake and RT as the One-RM testing session. Before the exercise session started each participant put a Polar heart rate strap and watch on so we could monitor HR at rest as well as throughout the session. They were then connected to the calibrated metabolic cart for ten minutes to measure baseline (resting) $VO_2$ in a seated position. Once the baseline $VO_2$ was collected the participant was disconnected from the metabolic cart. A baseline (resting) HR, RPE, and a baseline (resting) lactate measurement (using a lactate measurement device, lactate strips, and a needle stick) were measured immediately after the ten minutes of rest. Once this data was collected the participants completed a dynamic warm-up. The warm-up for both the HIIT and SUPER sessions consisted of: 10 push-ups, 15 body-weight squats, 20 walking lunges, and a dynamic arm and shoulder stretch using 5 lb. weight plates. After the warm-up was completed the participants were reconnected to the metabolic cart to resume the exercise protocols. The correct weights were loaded on to each bar and machine by assisting researchers to ensure smooth transitions through each exercise associated with the protocol. The HIIT protocol was completed first for all participants. The reason for this was the researchers wanted an equal VL for both the HIIT and SUPER exercise sessions. Since HIIT depends on a time allotted to do as many repetitions as possible and SUPER relies on a certain amount of repetitions we used the HIIT VL (sets x repetitions x weight) to calculate the amount of repetitions needing to be completed for each exercise when completing the SUPER protocol.

The HIIT session consisted of each of the six exercises done separately for sets of three before moving on to the next exercise. Each exercise was completed for 30 seconds with a 15 second RI given between each set. 50% of the achieved One-RM weight was used for each exercise. Each participant was to complete as many repetitions as possible in the 30 seconds allotted until time ran out or until fatigue resulting in failure of successful repetitions occurred, at which point they would have to hold the weight in the resting position. Only after the 30 seconds was completed was the participant able to set down the weight. The exercise order remained the same for HIIT as it was for the One-RM testing (bench press, bent-over row, bicep curl, lying triceps extension, leg extension, lying leg curl). For example, the three sets of bench press were completed before the participant moved on to the three sets of bent over row.

$VO_2$, lactate, RER, HR, total Kcals (aerobic), and RPE were measured at rest (baseline), throughout the exercise session, and immediately after the last repetition of the last exercise at which point the exercise session was considered complete. Lactate was measured twice, once after the ten minute resting period and once at the completion of the exercise session two minutes after the final set of lying leg curls (Scott, Littlefield, Chason, Bunker, & Asselin, 2006). $VO_2$, RER, RPE, total Kcal (aerobic), and HR were all collected at rest (baseline) and after every set throughout the exercise session (a total of 19 times). All data was recorded individually and then again on a master form created for this study. After the session was completed the participant was scheduled for their last session using the SUPER training protocol.

**Superset Resistance Training Protocol**

The same dietary and exercise restrictions used for the One-RM and HIIT sessions were used prior to the SUPER exercise session. The same resting measurements were completed as well, after which the same warm-up as used in the HIIT session was completed. For the SUPER protocol 70% of One-RM was used for each exercise, the amount of repetitions completed was calculated using the VL (sets x reps x weight), where the weight was always 70% of One-RM and the sets was always equal to three.

The SUPER session consisted of completing two exercises back-to-back with rest given only after the paired set was complete. Therefore, the bench press and bent-over row were completed together, the bicep curl and triceps extension were paired, and the leg extension and lying leg curl were completed together. Each paired set of exercises would be completed three times before moving on to the next group of exercises. Each pair of exercises would be completed back-to-back with no rest between, then a 60 second RI would be given before the next set of the same paired exercises were started. If a participant could not complete the set the spotter would assist them until they met the mandatory amount of repetitions needed to match the VL of the HIIT session. This continued until all three sets of each paired set of exercises were completed at which point the participant would move on to the next set of exercises, being given only a 60 second RI when transitioning between paired sets. Lactate was taken at rest and two minutes after the completion of the entire exercise session. $VO_2$, RER, RPE, total Kcal (aerobic), and HR were each collected at rest (baseline) and after every set throughout the exercise session including between the paired sets (a total of 19 times).

**Data Analyses**

To analyze the aerobic energy expenditure for each individual in the study $VO_2$ measurements were calculated by converting $VO_2$ into calories expended using an RER of 1.0 and the associated caloric equivalent of 5.05 kcal/$L^{-1}$ (Peterson et al., 2004; Ratamess et al., 2014; Robergs et al., 2007) which was done by the metabolic cart. Lactate measurements were utilized to calculate the anaerobic energy expenditure of each individual. Measures of lactate were converted to oxygen equivalent values as 3 ml $O_2$/$kg^{-1}$ body weight per millimole of blood lactate, then converted to kilojoules as 21.1 kJ per liter of $O_2$, and lastly converted to Kcal by dividing the total kJ by 4.184 which in turn can give us an accurate measurement of anaerobic energy expenditure (Scott, 2006). Aerobic and anaerobic caloric calculations were then combined to give us a total overall energy expenditure.

Data for all variables was analyzed using SAS 9.3 (Cary, NC). Separate paired *t*-tests were used to compare HIIT with SUPER for aerobic energy expended, anaerobic energy expended, and total energy expended which was determined by summing the aerobic energy expended and anaerobic energy expended. Measurements of $VO_2$, RER, RPE and HR were all analyzed using a within subjects ANOVA with repeated measures. Statistical significance was determined by $p < 0.05$.

# CHAPTER IV. HIGH-INTENSITY INTERVAL TRAINING VS. SUPERSET TRAINING: A COMPARISON OF ENERGY EXPENDITURE[1]

## Introduction

[1]Muscle strength and endurance are necessary for completion of day-to-day activities and to ensure success in athletic competition and exercise training (Astorino et al., 2012). Resistance training (RT) is a well-recognized method for improving health and fitness levels for most populations (Bloomer, 2005; Hunter et al., 2012; Robergs et al., 2007; Uchida et al., 2009). RT is a form of physical activity that is designed to improve muscular fitness by exercising a muscle or muscle group against external resistance (Esco, 2013). There are multiple forms of RT, each of which is designed to meet the specific goals or needs of the participants using them. There are various aspects that can be altered when completing resistance training. Among these are sets, repetitions, external resistance (e.g. weight), rest intervals, and exercise order. When these RT variables are used correctly they can help people achieve goals related to muscular endurance, hypertrophy, weight loss, weight gain, flexibility, and body composition. Although there is a large amount of research that has used RT to study results relating to fitness, research has yet to compare high-intensity interval training (HIIT) to reciprocal supersets (SUPER), also known as agonist-antagonist superset training in comparison to energy expenditure. The purpose of this study is to determine and compare the energy expenditure between two different types of RT: HIIT and SUPER.

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[1] The material in this chapter was co-authored by Jacob Erickson and Donna Terbizan. Jacob Erickson had primary responsibility for recruiting participants, designing the methods of the study, scheduling the participants, administering the exercise tests, collecting data, and analyzing and interpreting data. Jacob Erickson was the primary developer of the conclusions that are advanced here. Jacob Erickson also drafted and revised all versions of this chapter. Donna Terbizan served as proofreader and checked the math in the statistical analysis conducted by Jacob Erickson.

HIIT has recently been used as an alternative to traditional endurance training to improve cardiorespiratory fitness, as represented by maximal oxygen uptake ($VO_2$max) (Astorino et al., 2012). Much of the active population is familiar with traditional resistance training, which involves completing a set of repetitions to failure followed by an adequate rest period before subsequent bouts of the same exercise (Kelleher et al., 2010). In contrast, HIIT RT involves repeatedly exercising at a high intensity for 30 seconds to several minutes, separated by 1-5 minutes of recovery (either no or low intensity exercise) (Shiraev & Barclay, 2012). There have been multiple studies completed showing the health benefits of participating in HIIT exercise programs for athletes as well as the general population. HIIT is also one of the most frequent training methods used in anaerobic and aerobic type sports (Meckel et al., 2011). HIIT can be used with aerobic exercises, resistance weights, body weight, or in many other fashions. Many of the HIIT studies conducted thus far consist of exercise programs using ergometer bikes and treadmills. For this study only RT exercises were used; no traditional forms of endurance training were involved (e.g. running, cycling). One crucial variable associated with HIIT is the rest interval (RI) between sets (Astorino et al., 2012; Ratamess et al., 2007; Zuniga et al., 2011). The length of the RI depends on the goal of the individual. Short rest periods are typically recommended for RT programs designed to maximize muscle hypertrophy because short rest periods augment the growth hormone response when compared with longer rest periods (Rahimi et al., 2010). Laurent, et al. (2014) demonstrated that the optimal work-to-rest ratio is 2:1, as it elicits an optimal training intensity with little benefit gained by affording extra recovery time.

SUPER exercise programs consist of performing two consecutive exercises on opposing muscle groups while limiting the rest duration between exercises (Kelleher et al., 2010). A great example of a SUPER exercise combination is the bench press followed by the lateral pull-down

(Balsamo et al., 2012). The bench press works the chest and triceps muscles while the pull-down works the back and biceps muscles. This makes it possible to go from one exercise to the next with very little rest due to the fact the participant is exercising different muscle groups. Other studies have used agonist-antagonist RT protocols, calling them paired sets, comparing the total VL completed. (Robbins, Young, & Behm, 2010; Robbins, Young, Behm, et al., 2010). SUPER programs are commonly used by athletes and other resistance training participants to elicit hypertrophy. One study states SUPER is likely to produce greater metabolic energy costs than traditional RT because of the reduced recovery time, which leads to greater metabolic perturbation and fatigue (Kelleher et al., 2010). The current study took this theory into account when forming the hypothesis of HIIT expending more energy that SUPER due to decreased RI. RPE was also measured to see if there was any correlation between fatigue and energy expenditure.

## Methods

### Experimental Approach to the Problem

All subjects participated in a two-test, crossover research design. One repetition maximum (One-RM) strength testing was completed 7-10 days before the first exercise session. Participants then completed two exercise testing sessions with a recovery period of a minimum of 72 hours, but no more than 7 days, between each test. Participants were not to eat within three hours of any testing session, were not to smoke, consume alcohol, caffeine, creatine, energy drinks, pre-workout supplements, or other ergogenic aids within 12 hours of testing, and were to avoid resistance training for 48 hours immediately prior to each session. They were also instructed to be hydrated to avoid dehydration during each exercise session and not to drastically alter their diet throughout the study. This experiment was designed to focus specifically on the

RI given between sets of RT with an equal volume load (VL) in order to compare the overall energy expenditure between HIIT and SUPER RT programs. Since it is already known that total energy expenditure is related to total VL, the VL was matched for each of the exercise sessions. Therefore, the HIIT and SUPER sets were matched for exercise sequence, repetitions, and sets. Weight for each session was calculated as 50% of One-RM for the HIIT session and 70% of One-RM for the SUPER session.

The HIIT session was completed first by all participants since there was no set amount of repetitions that needed to be completed, the participants only needed to complete as many repetitions as they could in each of the three sets of each exercise in the 30 seconds allotted/set. Using the repetitions completed in the HIIT session, calculations of the number of repetitions that needed to be completed for each individual exercise in each set of the SUPER session to have matching VL were performed. Resting energy expenditure was assessed for 10 minutes prior to each of the exercise sessions, and baseline $VO_2$, lactate, RER, RPE, total Kcal (aerobic) and HR were established. After the baseline measures were taken each participant completed a dynamic warm-up, which was identical for both sessions, then began the exercise session. $VO_2$, HR, RER, RPE, and total Kcal (aerobic) were measured at baseline and after each set (total of 19 times), while lactate was measured at baseline and two minutes after the completion of each exercise session (total of two times for each session). Sessions were to be completed a minimum of 72 hours, but no more than 7 days apart at the same time of the day in order to maintain consistency in the study and subjects.

### Subjects

Twelve resistance trained men (23.91 ± 3.58 years; 180.87 ± 6.24 cm; 86.86 ± 5.05 kg) participated in the study. Resistance trained individuals were used exclusively for this study to minimize the risk of injury associated with the resistance training. Resistance trained was defined as someone who has participated in RT at least twice a week for a minimum of six months immediately prior to the study. All research procedures were approved by the university's Institutional Review Board, and all subjects signed and approved a written informed consent form before participation.

**Procedures**

*One Repetition Maximum Strength Testing*. A certified personal trainer was present at all sessions to ensure all subjects adhered to proper technique during their One-RM testing and exercise sessions. After a warm-up, initial One-RM attempt values were 90% of self-estimated One-RM. Each subject attempted progressively heavier weights until they could not complete one repetition with correct form on their own. Two minutes of rest was given between attempts with the last successful attempt being recorded as the participant's One-RM for each exercise. The exercises performed in this study were the bench press, bent-over row, bicep curl, lying triceps extension, leg extension, and lying leg curl, in that order, the same order was also used for the HIIT and SUPER testing sessions. The order was established by placing compound exercises before isolation exercises and all upper body exercises before lower body exercises to prevent pooling of blood in the legs (Kelleher et al., 2010). All One-RM testing was completed on the same day and at least 72 hours before the start of the HIIT exercise session since all participants were familiar with the exercises being performed.

*Exercise Sessions*. The final One-RM load achieved was used to calculate 50% One-RM for each exercise for the HIIT session. After the baseline measurements and the dynamic warm-up each participant completed all three sets of each exercise at 50% One-RM for 30 seconds with a 15 second RI between sets before moving on to the next exercise. During each set each participant was asked to complete as many repetitions as possible. If fatigue were to set in they were to hold the weight in the resting position of the lift and to complete as many more repetitions as they could before the allotted 30 seconds was complete. Only after completing each 30 second exercise interval was the participant allowed to set down the weight for the 15 second RI which followed. The same 15 second RI was given when transitioning between exercises as well.

The calculated load for the SUPER session was established at 70% of the One-RM achieved for each exercise. The amount of repetitions completed for each exercise set was calculated using the VL (sets x repetitions x weight) of each exercise completed during the HIIT session. Before the SUPER session could begin baseline measurements and a dynamic warm-up were completed once again. The SUPER session consisted of completing two exercises back-to-back with rest given only after the paired set was complete. SUPER exercise pairs were grouped in agonist-antagonist muscle groups. Therefore, the bench press and bent-over row were completed together, the bicep curl and triceps extension were paired, and the leg extension and lying leg curl were completed together. Each paired set of exercises would be completed three times before moving on to the next paired set of exercises. Each pair of exercises would be completed back-to-back with no rest between, after which a 60 second RI would be given before the next set of the same paired exercises were started. If a participant became fatigued the spotter would assist them until they met the mandatory amount of repetitions needed to match the VL of the HIIT session. This continued until all three sets of a paired set of exercises were completed at which point the participant would move on to the next set of paired exercises, being given only a 60 second RI when transitioning between one set of paired exercises to the next.

*Measures of Height, Weight, Heart Rate and Rate of Perceived Exertion*. All data was recorded on custom data sheets created specifically for this study. Height was measured using a Seca Stadiometer (Seca, Chino, CA) and weight was recorded using a Detector Eye-Level Scale (Detector, Webb City, MO), both immediately before the start of the One-RM testing session. Baseline HR was recorded using a Polar heart rate monitor chest strap and watch (Heart Rate Monitors USA, Warminster, PA) after the ten minute resting phase before the dynamic warm-up began. After each session began HR was recorded immediately after each of the 18 sets (a total of 19 times per session with baseline included). RPE was measured using Borg's Rating of Perceived Exertions 15-Grade Scale, which was printed on a piece of paper so each participant could easily point out their RPE throughout each exercise session. RPE was recorded after the ten minute resting phase prior to each exercise session began as well as after the completion of each individual set during both exercise sessions (19 times total).

*$VO_2$, Respiratory Exchange Ratio, Total Aerobic Kcal*. A Medgraphics metabolic cart (St. Paul, MN) was used to get an accurate measurement of aerobic energy expended during each exercise session. After the mouthpiece was inserted into the mouth and a ten minute seated resting phase was completed, baseline $VO_2$ (ml/kg/min) and RER were recorded before each resistance training session. RER was calculated by the metabolic cart, which analyzed the ratio of $CO_2$ produced to $O_2$ consumed. The mouthpiece was removed after the resting phase and then reinserted before the start of each exercise session. Baseline of the total Kcal measurement was recorded immediately at the start of the first set of the each exercise session since it kept a cumulative total of the amount of aerobic energy expended throughout each exercise session. $VO_2$, RER, and total aerobic energy expended (Kcals) were recorded from the metabolic cart at baseline and after every individual set throughout both exercises sessions (19 times total each).

*Lactate Measurements*. Lactate was analyzed to get an accurate measure of the anaerobic energy expended during each exercise session. Lactate measurements were taken twice per exercise session. One was taken immediately after the ten minute resting phase before each workout began and one was taken two minutes immediately after the last repetition of the final exercise set. Lactate was measured using a lactate tester and lactate strips (Lactate Plus, Hawthorne, NY) by means of a blood draw. The blood was drawn using a B-D Lancet 100 (Sports Resource Group Inc., Hawthorn, NY) to administer a finger prick to each participant. A blood sample was then taken using the lactate tester and strips to analyze lactate levels in the blood measured in millimoles (mmol). Anaerobic energy expended was calculated by subtracting the resting lactate measurement from the post-exercise lactate measurement. Measures of lactate were converted to oxygen equivalent values as 3 ml $O_2$/kg body weight per mmol of blood lactate, then converted to kilojoules as 21.1 kJ per liter of $O_2$, and lastly converted to Kcal by dividing the total kJ by 4.184 which in turn gave us an accurate measurement of anaerobic energy expenditure (Scott, 2006).

**Statistical Analyses**

Data for all variables was analyzed using SAS 9.3 (Cary, NC). Separate paired *t*-tests were used to compare HIIT with SUPER aerobic energy expended, anaerobic energy expended, and total energy expended which was determined by summing the aerobic energy expended and anaerobic energy expended in the form of Kcals. Measurements of $VO_2$, RER, RPE and HR were all analyzed using a within subjects ANOVA with repeated measures. Statistical significance was determined by $p < 0.05$.

## Results

### Energy Expenditure

When comparing energy expenditure there was a significant difference in all both aerobic and anaerobic energy expenditure as well as total energy expenditure. Aerobic energy expended was greater during the SUPER session, while anaerobic energy and overall energy expenditure were greater during the HIIT session (Table 1). Resting lactate levels showed no significant difference when comparing the pre-exercise lactate levels before each exercise session (Table 1).

### $VO_2$, RER, RPE, HR

$VO_2$ and HR showed no significant difference when comparing the two exercise sessions (Table 1). RER and RPE were both shown to have a significant difference when comparing the two sessions. RER and RPE were both significantly higher in the HIIT session (Table 1).

Table 1. Mean ± SD, and *p*-value for each variable (*denotes significance)

| **Variable** | **HIIT (mean ± SD)** | **SUPER (mean ± SD)** | ***p*-value** |
|---|---|---|---|
| Aerobic Energy Expenditure (Kcal) | 132.1 ± 13.03 | 152.7 ± 15.98* | < 0.0001 |
| Resting Lactate Level (mmol) | 1.4 ± 0.89 | 1.39 ± 0.83 | 0.9835 |
| 2-minutes Post-Exercise Lactate Level (mmol) | 15.56 ± 2.49 | 10.83 ± 2.42* | < 0.0001 |
| Anaerobic Energy Expenditure (Kcal) | 214.3 ± 42.33 | 142.8 ± 34.08* | 0.0002 |
| Total Energy Expenditure (Kcal) | 346.4 ± 47.4 | 295.5 ± 45.65* | 0.005 |
| $VO_2$ (ml/kg/min) | 17.29 ± 4.85 | 18.94 ± 6.08 | 0.0801 |
| Respiratory Exchange Ratio | 1.29 ± 0.17 | 1.18 ± 0.17* | < 0.0001 |
| Rating of Perceived Exertion | 14.81 ± 3.41 | 12.73 ± 3.81* | 0.001 |
| Heart Rate (BPM) | 146.73 ± 30.23 | 140.69 ± 26.42 | 0.398 |
| Total Time for Session (mm:ss) | 13:16 ± 00:02 | 14:45 ± 00:51* | < 0.0001 |

## Discussion

The major findings of the current study were that aerobic energy expenditure was greater in the SUPER session, possibly due to the fact that it took more time on average, but anaerobic and total energy expenditure were both significantly greater in the HIIT session. Since the VL was matched these findings allow us to better understand how RI and One-RM percentage can affect overall energy expenditure. RT using heavy loads, low repetitions, and a moderate-to-high number of sets are typically performed to maximize strength gains (Uchida et al., 2009). However, moderate to heavy loads with moderate-to-high repetitions and multiple sets per exercise are characteristics of muscle hypertrophy training as well (Uchida et al., 2009). Uchida et al. (2009) showed that no matter what the fitness level of the participant exercising, a VL can be set up at a lighter or heavier resistance and can elicit similar energy expenditure and hormone function. The study by Uchida et al. (2009) coincides with the current study in showing that the overall percentage of One-RM is not the only variable that predicts the amount of energy expended. Another study that supported this theory used a variable load program utilizing a high rep to low weight protocol vs. a high weight to low repetition protocol where each yielded similar results in energy expenditure (Thornton et al., 2011). The combination of these studies show that VL is just a part of the equation.

As stated previously, research has yet to compare a HIIT RT exercise protocol to a SUPER exercise protocol. HIIT and SUPER have been compared to traditional RT in previous studies, which has helped lead the way in forming hypotheses and ideas as to how to expend the most energy using a variety of methods. In general, the goal of HIIT is to enhance physiological, psychological, and metabolic overload by maximizing time spent performing high intensity exercise. HIIT can be used with aerobic exercises, resistance weights, body weight, or in many other fashions. During HIIT, the ability to maintain adequate overload without critical disruption of homeostasis leading to premature fatigue is controlled by either duration of the interval or duration of the recovery period (Laurent et al., 2014). The intensity of HIIT depends on the type of exercise being done, the number of repetitions, the number of sets, the length of each set, and the rest interval between sets. Increasing weight, exercise time, and/or repetitions will increase the volume and intensity of the workout. Decreasing rest time between sets will elicit the same effect. HIIT has been known to result in many positive benefits in the human body, eliciting adaptations in both oxygen-dependent and independent metabolism and is practical for many exercisers because of its minimal time commitment vs. aerobic exercise (Astorino et al., 2012).

Similar to the study by Kelleher et al. (2010), the goal of this study was to measure the aerobic, anaerobic, and overall energy expenditure using matched VL while altering the RI between sets when comparing two different exercise protocols. In the study by Kelleher et al. (2010) they found no significant difference in energy expenditure between the SUPER session and traditional session, but since the SUPER session took less time and expended similar amounts of energy it was hypothesized to be more efficient. Another study compared paired sets to traditional sets of bench press and bench pull and which showed that a higher volume of exercise could be completed when using SUPER over traditional RT methods (Robbins, Young, & Behm, 2010).

RI was one of the main variables monitored in the current study. RT makes demands on the phosphagen, glycolytic, and mitochondrial energy systems (Robergs et al., 2007) and the length of each RI is what allows these energy systems to replenish themselves. In this study we were able to show that a shorter rest interval was more efficient in expending more energy, even when using identical exercises, less weight, and a matching VL, also important was that the HIIT session was shorter on average furthering the belief that RI is crucial to overall energy expenditure in relation to RT.

When analyzing $VO_2$ and HR in this study no significant differences were seen between the two exercise sessions. The SUPER session resulted in greater $VO_2$ peaks, but also resulted in the largest variability between sets, possibly due to the replenishment of oxygen during the extended RI Although the $VO_2$ of the HIIT session seemed to be more linear than that of SUPER, both seemed to increase and decrease in a similar fashion (Figure 1). When comparing the HR of both sessions the resulting data shows a similar linear response (Figure 2). These responses in HR may have been because neither exercise protocol allowed the participants a long enough RI to decrease their HR, therefore the HR stayed elevated. If we would have used longer RI for either the SUPER or HIIT session we may have seen a different result.

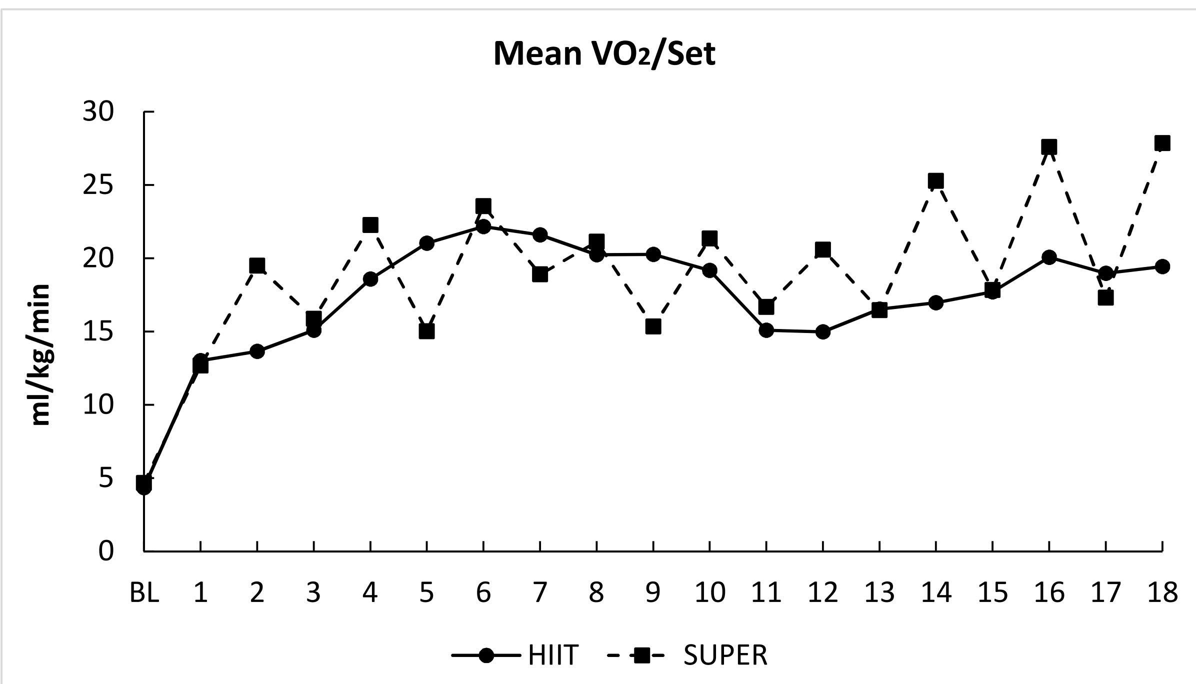


Figure 1. The mean baseline $VO_2$ (ml/kg/min) and the mean $VO_2$ for each set when combining data from all participants for both exercise sessions. The Y-axis represents baseline and the measurement after each individual set.

RER was significantly greater during the HIIT session than the SUPER session. RER between the two exercise sessions stayed pretty consistent until approximately set number nine (Figure 3). At this point the RER of the HIIT session seemed to stay elevated while that of the SUPER session declined slightly and became less consistent. This may have been due to the SUPER session allowing a long enough RI to replenish energy stores which would also explain the up and down pattern of the resulting data. A study by Ratamess et al. (2007) resulted in an RER that was significantly elevated during longer RI (two-minute, three-minute, five-minute) when compared to a short 30-second RI, but the current study resulted in a significantly higher RER during the HIIT session with shorter RI which means were weren't able to confirm the former study's findings.

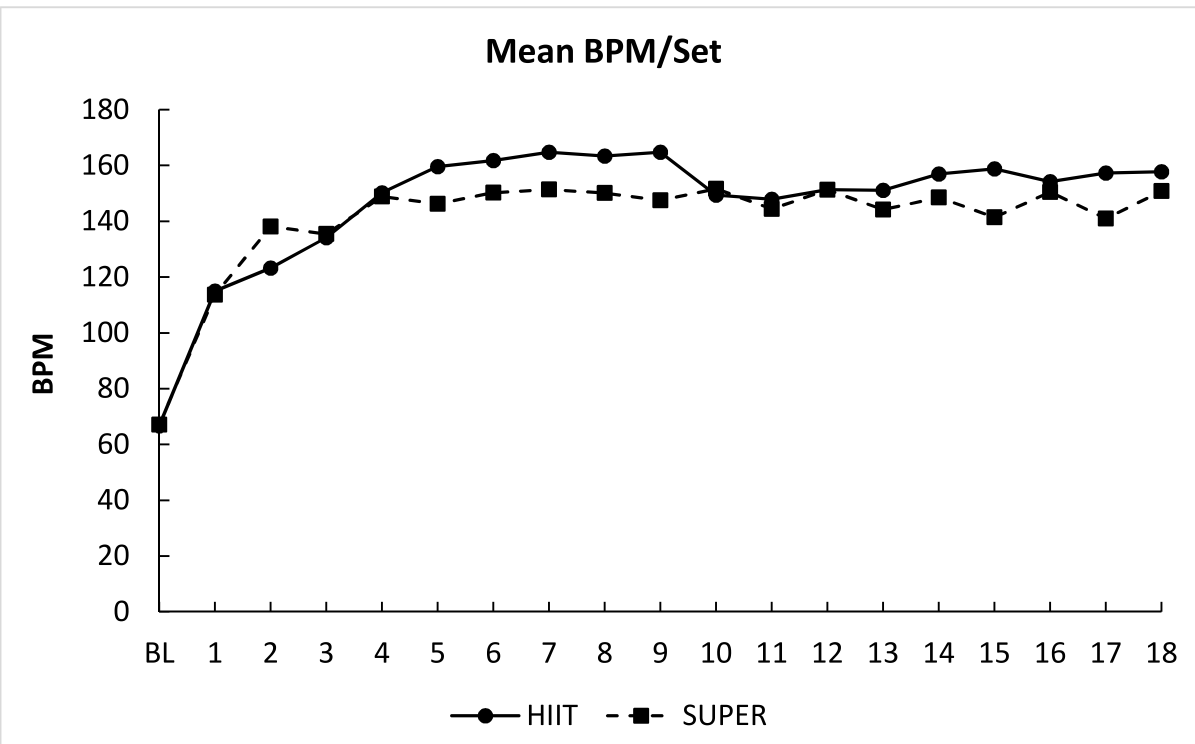


Figure 2. The mean baseline HR (BPM) and the mean HR for each set when combining data from all participants for both exercise sessions. Y-axis represents baseline and the measurement after each individual set.

RPE was also significantly higher during the HIIT session. The data allows us to see that the HIIT session resulted in a higher RPE with each consecutive set of an exercise while the SUPER session results stayed fairly linear with little change (Figure 4). When comparing RPE in a study with equated total work but differing work rates Kraft et al. (2014) found that post-set RPE was significantly higher when two sets of 12 repetitions with a 3-minute recovery period were performed compared to three sets of eight repetitions with a 1.5-minute recovery period using six different RT exercises despite matched work rates. The current study showed different results since the RPE was significantly higher in the HIIT session where the RI was shorter.

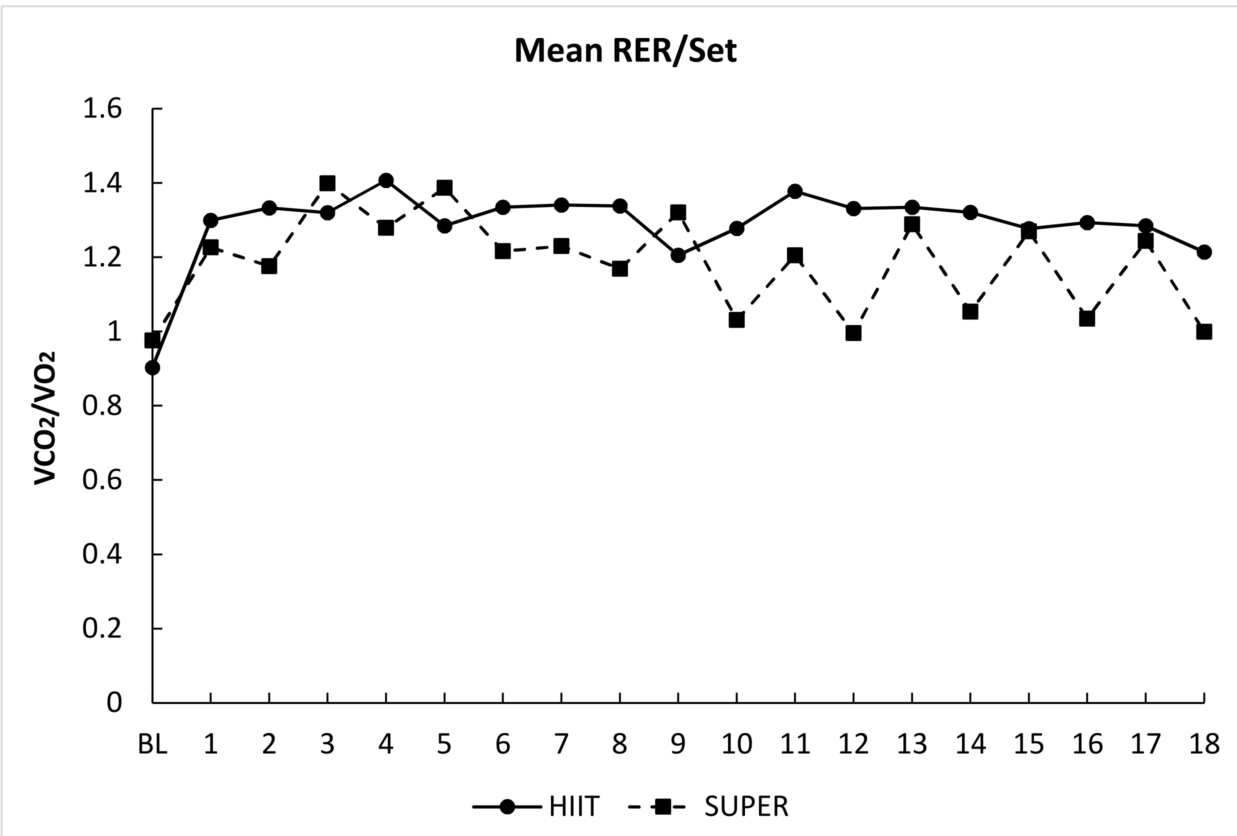


Figure 3. The mean baseline RER (VCO2/VO2) and the mean RER for each set when combining data from all participants for both exercise sessions. Y-axis represents baseline and the measurement after each individual set.

In conclusion, the purpose of this study was to determine if there was a difference in energy expenditure between two exercise programs, HIIT and SUPER. The researchers of this study were able to show that there were significant differences in aerobic, anaerobic, and overall energy expenditure. The study also showed that while $VO_2$ and HR were not significantly different between the two exercise sessions, the RER and RPE were significantly higher during the HIIT session. The results of this study were based specifically on healthy trained young men in northern North Dakota and Minnesota and may not be transferrable to other genders, fitness levels, or geographical regions. Future research based on energy expenditure may need to be experimented with over the long term with different populations in order to observe the effects of neuromuscular efficiency, muscular hypertrophy, and overall body composition to better suit our population as a whole.

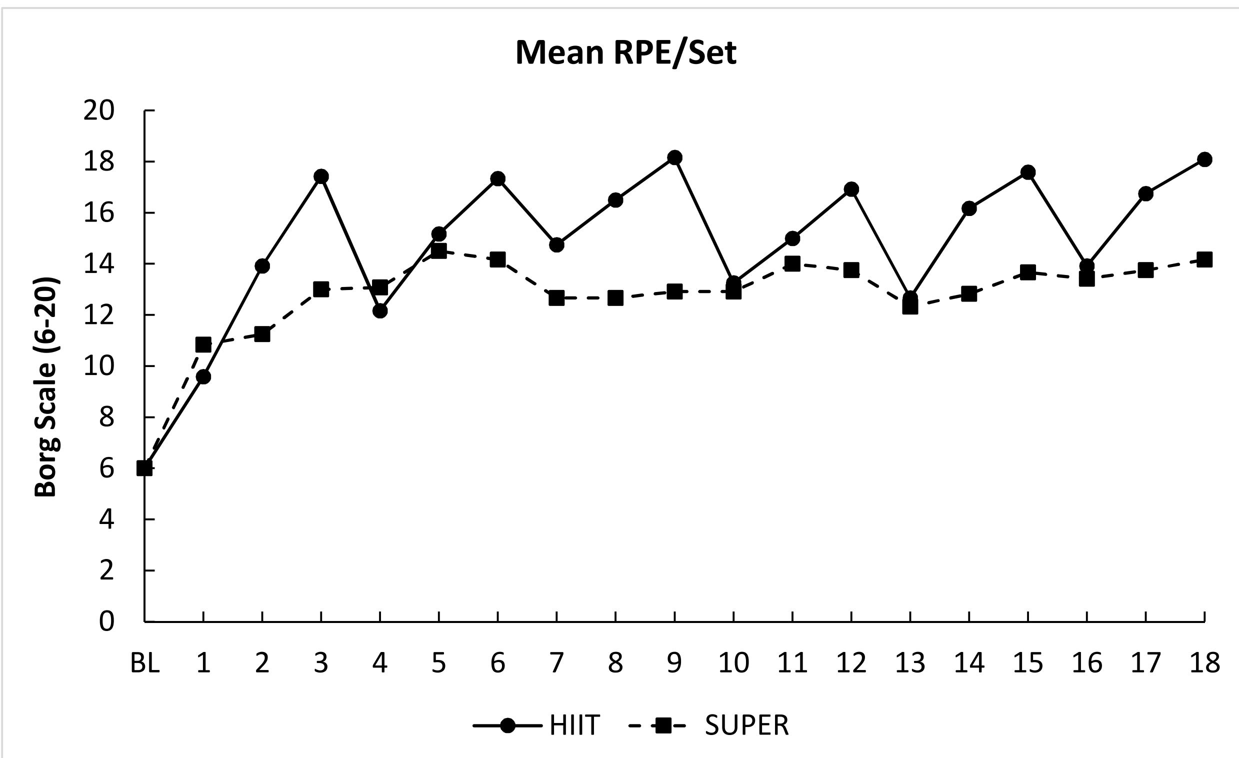


Figure 4. The mean baseline RPE (15-grade Borg Scale) and the mean RPE for each set when combining data from all participants for both exercise sessions. Y-axis represents baseline and the measurement after each individual set.

The current findings suggest that decreasing RI during a workout can be beneficial in individuals with the goal of expending greater amounts of overall energy. Also, the percentage of One-RM used for each RT exercise may not be as crucial as once thought as long as the VL completed is approximately equal to RT work-outs done using higher One-RM percentages per exercise. Using smaller percentages of One-RM may also aid individuals in maintaining proper form and avoiding injuries which will allow them to continue their exercise program as planned with less chance of a setback. The present study provides useful information for coaches, athletes, older adults, as well as all else in the general population who have a goal of expending large amounts of energy in the shortest amount of time.

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# CHAPTER V. SUMMARY AND CONCLUSIONS

The purpose of this study was to compare the amount of energy expended between two different RT programs. When using identical RT exercises in the two exercise programs, changing only the RI and percentage of One-RM lifted, we were able to show there was significant energy expenditure differences. The results of the study show that the SUPER exercise session expended significantly more aerobic energy than the HIIT session (HIIT 132.1 ± 13.03 Kcal; SUPER 152.7 ± 15.98 Kcal), $p < 0.0001$, but that the HIIT session expended significantly more anaerobic (HIIT 214.3 ± 42.33 Kcal; SUPER 142.8 ± 34.08 Kcal), $p = 0.002$, and total energy (HIIT 346.4 ± 47.4 Kcal; SUPER 295.5 ± 45.65 Kcal), $p = 0.005$, than the SUPER program using a matching VL. It is a possibility that the SUPER session elicited a higher aerobic energy expenditure due to the significant difference in time it took to complete the session (HIIT 13:16 ± 00:02; SUPER 14:45 ± 00:51), $p < 0.0001$, but no conclusions can be made based on this study's findings. This evidence may help determine how to better develop exercise programs based on goals surrounding weight loss and overall energy expended. Although some ideas have been formed basing energy expenditure around the percentage one lifts based on their One-RM, this study has shown that even at lower weights, more energy can be expended using a reduced RI between sets.

Other results from this study show that energy expenditure is not always related to other dependent variables of exercise. The $VO_2$ measurements between the two exercise programs showed no significant difference (HIIT 17.29 ± 4.85 ml/kg/min; SUPER 18.94 ± 6.08 ml/kg/min), $p = 0.0801$. Other studies that have altered RI using traditional endurance exercises may have had different results (Zuniga et al., 2011), but in this study when comparing strictly RT exercises no significant difference was seen. RER was another variable that has been studied in the past in relation to the type of energy being burned. This study showed HIIT to elicit higher RER levels than SUPER (HIIT 1.29 ± 0.17; SUPER 1.18 ± 0.17), $p < 0.0001$. RPE, which can be measured in a variety of ways, has been known to be significantly different when comparing different work rates and exercise programs (Laurent et al., 2014), once again RPE was higher in the HIIT session than the SUPER session (HIIT 14.81 ± 3.41; SUPER 12.73 ± 3.81), $p = 0.001$, which may have been due to participants completing repetitions faster during the timed HIIT program over the fixed repetitions SUPER program. Lastly, when comparing the mean HR between the two sessions no significant difference was seen (HIIT 146.73 ± 30.23 bpm; SUPER 140.69 ± 26.42 bpm), $p = 0.398$. Overall, our hypothesis that the HIIT session would result in a significantly higher energy expenditure than the SUPER session was confirmed. Also, RER and RPE were significantly greater in the HIIT session whereas $VO_2$ and HR showed no significant differences when comparing the two exercise programs.

In future research based around exercise programming, we should be conscious of monitoring RI and VL. By decreasing the external resistance of a RT exercise we can minimize the risk of injury while still maintaining our ability to expend an equal or greater amount of energy. Exercise programs should be based around the goals, fitness levels, and limitations of the individuals performing them, so rather than having each individual complete the same program, altering VL, RI, and exercise pattern to better suit each person may be safer and more effective. Lastly, since this study used only young resistance trained males, future research based on energy expenditure may need to be experimented with over the long term with different populations in order to observe the effects of neuromuscular efficiency, muscular hypertrophy, and overall body composition to better suit our population as a whole.

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# APPENDIX A. IRB APPROVAL

NDSU NORTH DAKOTA STATE UNIVERSITY

March 12, 2015

Donna Terbizan
Department of Health, Nutrition & Exercise Sciences

IRB Approval of Protocol #HE15174, "High Intensity Interval Training vs. Superset Training: A Comparison of Energy Expenditure"
Co-investigator(s) and research team: Jacob Erickson, Zachary Wyatt, Sean Mahoney

Approval period: 3/12/15 to 3/11/16
Continuing Review Report Due: 2/1/16

Research site(s): NDSU Funding Agency: n/a
Review Type: Expedited category # 4
IRB approval is based on the revised protocol submission (received 3/12/15).

Additional approval is required:
o prior to implementation of any changes to the protocol (Protocol Amendment Request Form).
o for continuation of the project beyond the approval period (Continuing Review/Completion Report Form). A reminder is typically sent 4-6 weeks prior to the expiration date; timely submission of the report is your responsibility. To avoid a lapse in approval, suspension of recruitment, and/or data collection, a report must be received, and the protocol reviewed and approved prior to the expiration date.

A report is required for:
o any research-related injuries, adverse events, or other unanticipated problems involving risks to participants or others within 72 hours of known occurrence (Report of Unanticipated Problem or Serious Adverse Event Form).
o any significant new findings that may affect risks to participants.
o closure of the project (Continuing Review/Completion Report Form).

Research records are subject to random or directed audits at any time to verify compliance with IRB regulations and NDSU policies.

Thank you for cooperating with NDSU IRB procedures, and best wishes for a successful study.

Sincerely,
Kristy Shirley

Kristy Shirley, CIP, Research Compliance Administrator

For more information regarding IRB Office submissions and guidelines, please consult www.ndsu.edu/irb. This Institution has an approved FederalWide Assurance with the Department of Health and Human Services: FWA00002439.

INSTITUTIONAL REVIEW BOARD
NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8995 | Fax 701.231.8098 | ndsu.edu/irb

Shipping address: Research 1, 1735 NDSU Research Park Drive, Fargo ND 58102

## APPENDIX B. DYNAMIC WARM-UP PROTOCOL

1. Ten push-ups
2. Fifteen body weight squats
3. Twenty lunges (ten on each leg)
4. Dynamic upper body stretching using five lb. plates

## APPENDIX C. ONE-REPETITION MAXIMUM PROTOCOL

1. Fill out PAR-Q and Informed Consent Form
2. Assign a number to the participant
3. Take height and weight measurements
4. Participant warm-up (they may warm-up however they want)
5. Start One-RM Testing
    a. Start with 90% of estimated One-RM and then progressively increase the weight until the participant cannot complete one repetition independently with proper form
    b. Two-minute break between sets
    c. Record results on HIIT data recording sheet
    d. Exercise Order
        i. Bench Press
        ii. Bent-over Row
        iii. Bicep Curl
        iv. Lying Triceps Extension (Skull Crusher)
        v. Leg Extension
        vi. Lying Leg Curl
6. Give the participant the restrictions form for the sessions

## APPENDIX D. HIGH-INTENSITY INTERVAL TRAINING PROTOCOL

1. Connect participant to metabolic cart, put on a HR monitor, and seat them for 10 minutes.
2. Position machines in the correct areas and load them with the correct weights (50% 1RM)
3. Give each research assistant the correct data form for their duty
    a. One will spot and record HR
    b. One assistant runs stopwatch and holds cords/hose
    c. One assistant counts and records repetitions and RPE (using sheet)
    d. One records total time, RER, $VO_2$, and Kcal sum
4. Record resting $VO_2$, RER, HR, RPE
5. Disconnect participant from cart
6. Record resting lactate
7. Have them complete warm-up
8. Re-connect participant to the metabolic cart
9. Start Protocol
    a. Three sets of each exercise - 30 second exercise/15 second rest intervals
    b. $VO_2$, RER, HR, RPE, immediately after each set
    c. Exercise order
        i. Bench Press
        ii. Bent-over row
        iii. Bicep Curl
        iv. Lying Triceps Extension
        v. Leg Extension
        vi. Lying Leg Curl

10. Record final set data (total 19 times each)

11. Wait two minutes

    a. Take final lactate measurement

12. Remove HR monitor

13. Confirm final scheduled time for last session

## APPENDIX E. SUPERSET TRAINING PROTOCOL

1. Connect participant to metabolic cart, put on a HR monitor, and seat them for 10 minutes.
2. Position machines in the correct areas and load them with the correct weights (70% 1RM)
3. Give each research assistant the correct data form for their duty
    a. One will count repetitions and record HR
    b. One assistant runs stopwatch and holds cords/hose
    c. One assistant counts repetitions and records RPE (using sheet)
    d. One records RER $VO_2$, and Kcal Sum
4. Record resting $VO_2$, RER, HR, RPE
5. Disconnect participant from cart
6. Record resting lactate
7. Have participant complete warm-up
8. Re-connect participant to metabolic cart
9. Start Protocol
    a. Three sets of each paired set, repetitions determine by HIIT volume load. (70% One-RM)
    b. HR, RPE, RER immediately after each set (19 times total)
    c. $VO_2$ every 30 seconds
    d. Exercise order
        i. Bench Press SS Bent-over row
        ii. Bicep Curl SS Lying Triceps Extension
        iii. Leg Extension SS Lying Leg Curl
10. Record final set data (total 19 times each) and last $VO_2$ measurement

11. Wait two minutes

    a. Take final lactate measurement

12. Remove HR monitor

## APPENDIX F. HIIT VS. SUPER PARTICIPANT RESTRICTIONS

Do your best to maintain your normal diet and lifestyle throughout your sessions. But here are a few restrictions I will ask you to stick to while you are participating in the study:

- Do not eat within three hours of a testing session.
- No smoking, alcohol, caffeine, creatine, energy drinks, pre-workout supplements or other ergogenic aids within 12 hours of a testing session.
- Avoid resistance training the day before and day of your testing sessions.
- Try to stay hydrated and do your best not to alter your diet drastically.

Thank you for participating if you have any questions or scheduling conflicts please contact Jake Erickson by phone/text at 320-080-0345 or by email at jacob.e.erickson@ndsu.edu.

## APPENDIX G. PARTICIPANT RECRUITMENT SCRIPT

High-Intensity Interval Training vs. Superset Training Recruitment Script for Subject Recruitment in Classes

Hi, my name is Jake Erickson and I am a graduate student in the Health, Nutrition, and Exercise Science program. I am conducting a study on energy expenditure using two different types of resistance training programs: high-intensity interval training, also known as HIIT, and superset training.

There are many different kinds of high-intensity interval training but for this study you would be completing as many repetitions of an exercise as you are able for 30 seconds followed by a 15 second break at 50% of one-repetition maximum. This is repeated three times for each exercise using six different exercises for a total of 18 sets. Superset training consists of combining two resistance training exercises that use opposite muscle groups back-to-back with a 60 second break between each paired-set at 70% of one-repetition maximum. This is done three times for each of the three paired sets for a total of 18 sets. These two sessions will be compared to measure the amount of energy used through aerobic and anaerobic energy measurements.

I am looking for up to 12 healthy male volunteers between the ages of 18-35 years old with a minimum of six months resistance training experience, at least twice a week. You should be injury free.

Participants will complete one "one-repetition maximum" session and two exercise protocol sessions. Each will take between 30-40 minutes. There is no compensation for participating in this study.