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The Effects of Moderate versus Variable High Intensity Cycling on Metabolic Responses during Recovery

Matthew Wolfe
mhwolfe@coastal.edu

Jenna Thompson
jmthomp4@coastal.edu

Justin Guilkey
jguilkey@coastal.edu

The Effects of Moderate versus Variable High Intensity Cycling on Metabolic Responses during Recovery

By

Matthew Wolfe

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Louis E. Keiner
Director of Honors
HTC Honors College

Justin Guilkey
Assistant Professor
Department of Kinesiology
College of Science

Abstract

PURPOSE: Examine oxygen consumption (VO_2), energy expenditure and respiratory exchange ratio (RER) during recovery following moderate-intensity exercise (MIE) and variable high intensity exercise (VIE) in healthy adults. METHODS: The two conditions were randomized and performed on separate days fasted. Both protocols commenced after 15-min seated rest. MIE protocol was at 40% of maximal work rate (WRmax). VIE consisted of sixteen 10-sec supramaximal sprints (120% WRmax), sixteen 20-sec high intensity bouts (60% WRmax) and low-intensity recovery (20% WRmax) interspersed throughout the exercise. Total duration and work were matched. There was 75 minutes of seated recovery. VO_2 and RER were recorded during exercise and every 15-minutes of recovery. Energy expenditure (EE) and fat oxidation were calculated. Significance if $p \leq 0.05$. RESULTS: During recovery, NET VO_2 decreased in both conditions from exercise to 75 minutes. There were no differences in NET VO_2 between conditions during recovery. Net EE during recovery was lower in MIE than VIE. During VIE and MIE, RER was 1.02 ± 0.4 and 0.96 ± 0.06, respectively (P=0.06). During recovery, RER was lower in VIE compared to MIE at 30 and 45 minutes but was similar at 15 and 60 minutes. At the end of recovery, RER for VIE and MIE were 0.89 ± 0.08 and 0.95 ± 0.09, respectively (p = 0.08). Fat oxidation at the end of recovery was significantly greater in VIE than MIE. CONCLUSION: Although, NetVO_2 and EE were similar during recovery, VIE appears to alter fuel utilization patterns during recovery towards a lower RER and greater fat oxidation.

Introduction

Regular physical activity has been shown over time to increase a person's overall quality of life and health. In general, there are a multitude of health benefits that can be gained from performing exercise on a regular basis. Some of these benefits include lowering blood pressure, increasing maximal oxygen consumption (VO_2max), reducing the risk of diseases (i.e. cardiovascular, metabolic), stress relief, strength gains, weight control, and reduced mortality rates (1). There are many types of exercise that can be utilized to attempt to maintain regular physical activity (2).

There are multiple theories about the optimal amount of exercise needed per week. However, in general the American College of Sports Medicine (ACSM) recommends moderate exercise should be conducted for a total of 150 minutes spread out throughout a week (1, 2). Moderate intensity exercise includes working at between 40-60% of VO_2max. However, vigorous exercise can be performed for 75 minutes to meet such recommendations. Vigorous intensity exercise includes performing exercise at 60-85% of the persons VO_2max (2).

There are different physiological responses to different exercise intensities. Some of the most common ways of exercising at a moderate intensity for a prolonged time at the same relative intensity (1). For example, one may walk at a 3% grade on a treadmill at 3 mph, for 20 minutes for an aerobic exercise. More recently exercise scientist and those in the fitness world have been experimenting with changing the intensity throughout an exercise bout (3). One way is through variable intensity exercise where you can fluctuate between going over 100% of normal work rate, a lower work rate around 20-30%, and a moderate work rate of about 50-60%.

For healthy adults, higher intensity training can be beneficial because it is a way to save time, and the amount of exercise done is greater but the intensity may be too much (4). The recommendations for this fall within the atypical ACSM guidelines of about 75 minutes spread out in a week (2). On the other hand, aerobic exercise can take a bit longer to perform and people may find it to become stagnate or boring (3). The benefits for higher intensity training can include similar benefits that moderate intensity exercise provides. Such as lowering blood pressure, lowering heart rate, and reduced risk of cardiovascular diseases (4). While at the same time cutting down on overall time exercising, and possibly increasing enjoyment (3).

Background

The overall metabolic health of a person can be affected by the exercise that they perform. Sedentary and overweight populations are at a disadvantage because of their lack in ability to switch fuel sources based on metabolism termed metabolic inflexibility (5). Increased metabolic flexibility is possible from continuing an exercise routine overtime. Exercise can help use stored glycogen by turning it into glucose to be used for energy. Without exercise the body can become reliant on fat as its main energy producer, causing excess storage of glycogen, insulin resistance, and eventually diabetes. Metabolic inflexibility is combated by the type of fuel utilization during exercise (5).

Fuel usage can depend on the intensity of the exercise. In healthy individuals, high intensity exercise causes there to be greater carbohydrate utilization. During a time of such high intensity the body will rely on its quickest source of energy through the breakdown of carbs (6). This will be reflected in a greater respiratory exchange ratio (RER) and should be higher (7). When the intensity varies throughout, the expectation is that the body will adapt to the current exercise intensity and may see a series of changes in RER (7). For moderate exercise, the expectation is that the body's usage of fuel would be rather similar throughout. It may be likely that the body will rely more on glucose, but at a lower RER when compared to the high intensity bout (6). During the recovery period of high intensity exercise an efflux may occur where the body switches to utilization fat oxidation for its recovery period (8). This would be in combination with the loss in glucose during exercise and the convenience of a slower paced energy system. Compared to moderate where we may see a change to reliance on fat oxidation, but not at as high as a level. In both cases a sudden change in RER could occur and, in this case, will be lower (7).

Variable intensity exercise is combination of high and low intensity training. It is a different way to balance the positives and negatives of higher intensity exercise and moderate continuous exercise. Its frequently changing may alleviate some negatives like working at too high of an intensity, and boredom. In comparison to high intensity exercise it could be safer because there is less time at vigorous intensities. However, it has the potential to provide the same amount of stress along with the same benefits of improving metabolic flexibility in comparison to high intensity training.

Significance of the Study

The initial interest of this research began with an idea of looking at post exercise responses in children. There are multiple differences between the way children's body's works in a metabolic sense in comparison to adults. Finding an optimal way for them to exercise was sought out. However, because of the limited access to children the focus of the study was shifted towards a young adult population. At the University the abundance of college aged students was a factor into changing the criteria and was a way to test out the study so it could eventually be transitioned into working with adolescents. Overall, the importance of comparing different exercise types can be narrowed down to two areas. One being from an exercise/health-oriented view in that which one is going to benefit the body the most. In this case the details recorded in the study such as RER, and VO_2 can be analyzed to see which method of exercise can increase the body's abilities. Another area that is helpful in comparison in the enjoyment and likelihood that the participants would exercise in that capacity again. If found, a method that promotes overall health exercise, in a shorter amount of time, and in an enjoyable manner would be the most ideal.

Purpose

The purpose of this study is to examine total and recovery energy expenditure, fuel use, EPOC and enjoyment during and after MIE, VIE in healthy college-aged men and women. The metabolic portions were studied to look for differences in responses from one protocol to the other. The perceptual responses of RPE, Affect, and the Physical Activity Enjoyment Scale (PACES) were recorded to look at the differences in enjoyment and feelings about the two different protocols.

Hypotheses

1. During MIE, RER would be lower in comparison to VIE this would show that MIE would use a greater percentage of fat during exercise and VIE would use a greater percentage of carbohydrates.
2. During VIE, EE would be greater in comparison to MIE because VIE has absolute higher intensities would could potentially add more stress to the body

3. During VIE, EE/EPOC would be greater in recovery vs MIE because of the greater anaerobic usage during the exercise bout
4. During MIE, RER Recovery would be higher in comparison to VIE because of the availability of carbohydrates left as fuel following exercise
5. VIE would be more enjoyable because of the changing intensity vs MIE where they may get bored.

Literature Review

General Fuel Use

Exercise is planned, structured, repetitive bodily movement produced by muscles that results in increased energy use (2). To meet the energy demand, there are three types of fuels that humans use primarily use. They are carbohydrates, fats, and protein. Humans rely on carbohydrates and fats for most energy requirements, specifically glucose, glycogen, and free fatty acids. Fuel use is the body deciding which type of nutrient and when it is appropriate to use such fuel . The decision made by the body can rely on what type of fuel is available and exercise intensity. Fuel use varies from person to person, however there is a consistent idea that fuel usage is somewhat similar between people of the same age (9). Adults tend to use the same type of fuel based on the intensity of the activity. An example of this is during exercise, adult's bodies may utilize carbohydrates for meeting energy requirements (9). These fuels are different in source, and how they are broken down by the body as well. The way the body metabolizes carbs is typically through anaerobic and aerobic glycolysis. These pathways are usually engaged during high intensity exercise. Free fatty acids are metabolized at a slower rate via oxidation usually during lower intensity exercise. However, can provide more adenosine triphosphate (ATP) than carbohydrates.

Free Fatty Acids (FFA) are broken down from triglycerides that are stored as either adipose or in the muscle as intramuscular triglycerides. At rest FFA is primary fuel source because of its ability to produce energy (10). Since it takes more time to break down and is widely available it is a useful fuel source at rest. Once energy demand increases glucose utilization increases, and the body begins to use a greater amount to create ATP via oxidative glycolysis. Glucose is primarily used during high intensity because it provides energy quicker and is available more readily in the muscle through glycogen. Glycogen is a combination of glucose molecules that is stored (11). It is stored in the liver and is also found in skeletal muscle. The liver form intended for whole body use, while the muscle glycogen is used for that sole muscle. The body can convert glycogen into glucose to maintain blood glucose and to meet metabolic needs in the body (11).

Respiratory exchange ratio (RER) measures the body's fuel use through the production of carbon dioxide and consumption of oxygen (7). For fuel use, RER can range from 0.70-1.0, 0.70 being oxidation of a fat molecule, and 1.0 is oxidized carbohydrates. At rest, an adult's RER is closer to 0.7, and when exercise begins it can go upwards towards 1.0. An adult can average an RER of about 0.75-0.85 during a resting period (7). An example of a resting RER may be 0.80, meaning that the body is mainly oxidizing fats during that time. RER is a useful method for easily determining the source of energy during exercise and is frequently used as a research tool. (7)

In healthy adults, fats are used in the fasted state because they are available in the blood. In the fed state there is a high flux of blood glucose and the body will release insulin which lowers blood glucose levels (12). Blood glucose is oxidized during a fed state since it is widely available in the blood and insulin moves it into muscle for oxidation. This ability to change substrate use when different substrates are available is metabolic flexibility (9, 13). The body should be able to assess its levels of fuel, and then based off this be able to decide which type of fuel is appropriate for the state of functioning. The key factors of metabolic flexibility include mitochondrial oxidation ability, adipose tissue ability to regulate fat oxidation, and the rate in which nutrients are taken up by the muscle (13). Fasted and fed RER are tangible measurements of macronutrient oxidation and ideally these two values would be at a balance to food composition and this would show the fuel use throughout that time. In instances of a high fat diet metabolic flexibility may be better observed, rather than during a hyperinsulinemic clamp (13). During a high fat diet, if the body is incapable to oxidize all of the lipids supply could lead to a difference in RER when compared to the composition of the food (7). Thus, leading to the body retaining more fat. It is only when the body is in a consistent state of oxidation consumption mismatch (in one example a high caloric diet/low activity levels) the flexibility be impacted by mitochondrial dysfunction caused by the adipose deposit. During states of fasting, in a healthy person would be closer to 0.7, however with mitochondrial dysfunction and fat deposits RER can increase over time leading to metabolic inflexibility (13).

Metabolically inflexibility is the inability to switch fuel sources based on availability, which can lead to a static RER regardless if in a fed or fasted state (13). Metabolic inflexibility occurs because of cell glucose intake is hampered as a result of insulin resistance. Insulin resistance is when the body is producing more insulin to return blood glucose level to their previous state (14). In cases of inconsistent nutrient intake, the body has been seen to have vast differences in RER. Fuel use can widely depend on the state of one’s nutritional availability, however we can see some similarities and general trends between groups such as adults or children (13). Being metabolically inflexible can increase the risk of insulin resistance (5). Early in insulin resistance, the pancreas’ secreted insulin does not bind correctly to receptors in the muscles, therefore the pancreas will produce more insulin. Thus, leading to the overuse of the pancreas and some people may become resistant to insulin if their pancreas can no longer produce it, or it is destroyed by other cells. The condition associated with this lack of insulin is well known as diabetes. (15)

Fuel use (Children)

At rest children have similar RER's when compared to adults (16). For research purposes this is to be more focused to the resting fuel use for boys. Resting RER's for these children as mentioned before have bene found to be similar in adults. In one study the resting RER of normal weight children (age= 10 years) was 0.81, Meaning that the children were mainly relying on fats for energy at rest (16). While the levels at rest for normal children were comparable to adults, the consensus is that children prefer to use more fat oxidation for energy. The reasoning behind this is not quite certain but there are several theories. One is that children cannot store as much glycogen in their muscles in mature glycolytic system and differences in hormonal response during exercise. (16)

Overweight Children's Fuel Use

Overweight children can be seen to have these issues having a harder time oxidizing fats, storing glycogen properly, and being able to respond to high insulin stimulation leading to metabolic inflexibility (15). Thus, leading to more problems with their health, possible type 2 diabetes. Overweight individuals, including obese children tend to be at a higher risk for developing metabolic inflexibility (15). When this happens, they may rely more on fat when compared to normal weight children. A study by Crisp (16), noted that at rest and during exercise the RER of overweight boys was similar when compared to the normal weight boys. Various studies have found that obesity and type 2 diabetes are on the rise in today's world (15). These two diseases are related to how a person responds to the fuel use that they choose for their body. It was concurrent that exercise was one of the biggest helps in reducing the negative components that come with the diseases. Thus, further investigation was necessary to determine the differences in the body's responses between these groups of people (adults, youth- normal and overweight).

Fuel use During Exercise

There are differences in fuel use between boys and men, and pre-pubertal and post-pubertal children during exercise (17, 18). During exercise youth populations tend to rely more on fat oxidation while adults use more carbohydrates. One study found resting RER were about the similar between a group of young men (age= 22 years) and a group of boys (age= 10 years) there was a difference during a cycling exercise. This study did two different trials one with a carb source during cycling the other with a placebo. What was found is that the boys RER during the placebo test was 0.91, while the men was 0.96, these were statistically different. During the carb trial, boys was similar to the placebo trial. Furthermore, the relative carbohydrate oxidation ($mg*kg^{-1}*min^{-1}$) was greater in men, and fat oxidation was greater in boys (17). In a different study, the researchers compared oxidation rates by pubertal status, ranging from pre pubertal to men. This study showed that youngest children have the highest rates of fat oxidation during exercise. As well as they mature the decrease in fat oxidation occurs in more mature children which was expected. In a third study, researchers supplied subjects with glucose drink then fructose plus glucose drink to examine youth carbohydrate oxidation during exercise. A substrate oxidation showed that the two carbohydrate trials had similar RERs compared to the placebo trials. In addition, the fructose plus glucose trials were not different (18). As seen from above, there have been various studies looking at fuel using while subjects were exercising.

Post Exercise Responses

While many articles have examined fuel use during exercise, few articles included research investigating the post exercise response. After 15-20 minutes of exercise recovery, the absolute carbohydrate oxidation in overweight boys was higher compared to normal weight children. At rest, RER was similar in the two groups, overweight boys RER was 0.82 and the normal weight RER was 0.81. In terms of fuel use, fat oxidation increased with exercise and during recovery but between the groups, there was no significant differences (16). The lack of differences between groups was not found in other studies. Most studies have found that RER for overweight boys is lower when compared to their normal weight counterparts. The researchers thought this may have been due to a difference in categorization of body composition, or the overweight children were not exercising at a similar intensity they may have experienced more fatigue. In another study, insulin levels were determined to not be significantly different in the two groups who were given the carbohydrates during the post exercise period. The plasma FFA in the placebo trial remained higher and for longer when compared to the other two CHO trials. The RER levels for the two CHO trials were at a higher rate as expected. During the post exercise period the fat oxidation was highest in the exercise placebo group, meaning that the body was mainly using fat as it substrate for the recovery period (19). A reason for this could be plasma FFA stayed at a greater concentration during the recovery period. Higher FFA concentrations have been correlated to more body fat oxidation and even increases in muscle (20). They also have been shown to inhibit carbohydrate utilization (21). While there may be some useful data on post exercise response, more research is needed to obtain knowledge about a younger bodies' response. Thus, future research needs to investigate more into information about how overweight children respond after exercise and the steps that need to be taken to best help the children. Through the response, proper exercise protocol and treatment can be given to these overweight children who may be more susceptible to diseases.

Common Fuel Use Method

In some of the more relevant studies to fuel use, have similar methods and modes of the exercises given to the subjects. In one study the exercise for parts A and B was directed at 70% of VO_2 peak, up to 400 kcals of expenditure (3). Prior to the study, baseline metabolic rates were taken via indirect calorimetry. They also completed a submaximal exercise test where the mode was a cycle (22). In the study that looked at all portion of response in children the methods included a VO_2 peak test in which the mode was a treadmill protocol. The methods to determine the substrate utilization were at rest- the subjects were brought in after an overnight fast and were attached to a gas analyzer to gather RER data. The exercise portion was done at a 50% VO_2 peak and continued for 10 minutes, and the post exercise was gathered in 5 minutes intervals up to 30 minutes. An overall review included over 7 studies where the studies of obese children, were divided into aerobic and combined programs. The aerobic programs mainly aerobic training and aerobic exercise. They averaged about 10-12 weeks, and sessions lasted about 30-60 minutes. The combined programs involved cycling, walking, sports, and games. In another study, methods were daily and consisted of about 2 hours of high intensity activities including tennis and gym-based routines (3). They subject goal was to attain around 70-85% of maximum heart rate during the exercise. Some of these may be more realistic in terms of time and workload than others. Ideally a shorter amount of time with a higher workload may be more reasonable. A common goal to keep in mind was keeping the children attentive and interested. However, the different use of percentage VO_2max or percentage maximal heart rate (HRmax) may be useful in prescription. Along with these methods, some studies exercise was included, the outcomes were beneficial in metabolic health. There was often a decrease in risk factors such as BMI, and body fat. As well as a decrease in cholesterol, blood pressure, and heart rate (3). As exercise researchers it is consistent in our area of focus that exercise is almost always beneficial. This concept can be correlated over into the lives of the overweight children and applied in a manner that is effective. The key to this is finding methods that help physiologically and can maintain the goals of the children as well. ***Conclusions***

Fuel usage can give researchers an idea of how a person's body is responding to its energy requirements (at rest, exercise, recovery from exercise). While many researchers have focused on the response during exercise, the post exercise portion could be important in being able to identify a balanced plan for exercise, especially with overweight children. Various diseases that affect people today such as diabetes, and obesity are on the rise and as researchers it is important to try to find the best ways to prevent or reverse them.

Methods

Experimental Outlines for the Study

All sessions were performed in a fasting state in the morning. They were performed in the body composition laboratory where a stable temperature and barometric pressure were maintained. The first day for each subject began with a VO_2max test along with other body measurements. The subjects were asked to come in for a total of three sessions which were spread out with at least one day in between. The work rate for the tests were matched, and the order of the tests was randomized. After the initial visit and the subjects were asked to come fasted in the morning from the night before.

Subjects

A total of 10 subjects were recruited. A pre-exercise form was filled out to attain basic information about the subjects including their weekly activity. While there was no requirement of meeting a certain amount of physical activity each week, most subjects were recreationally active in their daily lives. Activities included resistance training, walking, cycling, and various sport-like activities. The age range for the subjects was set to be younger adults of ages 18-35 years old. Medical questionnaire's and consent forms were filled out upon arrival of the first visit to verify there was not outlying risks for the participants. An institutional review board was conducted an approved prior to the study being performed.

Baseline Testing

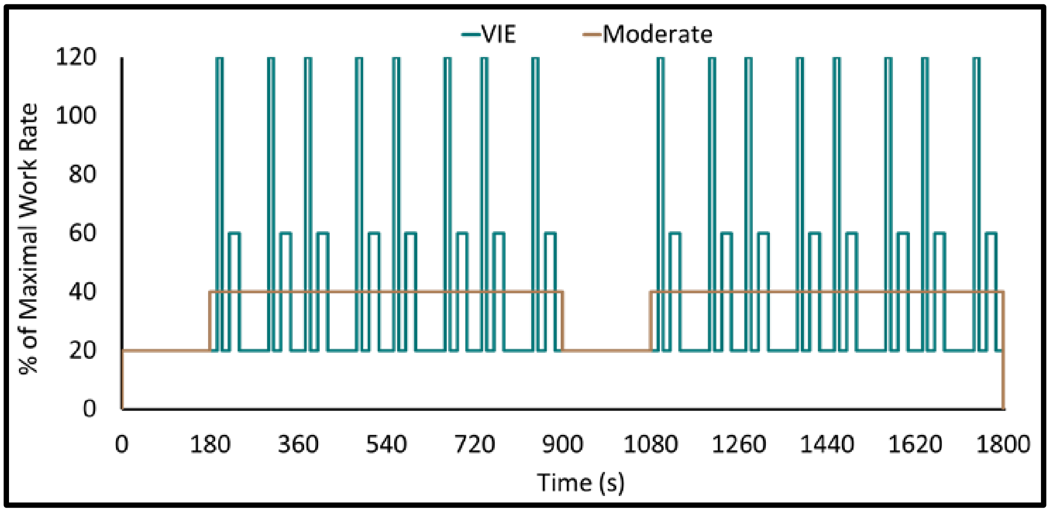
During the initial visit, the participants filled out consent forms and medical questionnaires. Initially the subject's height and weight were taken. Then they proceeded to be placed into a fully calibrated BOD-POD machine to get an accurate body composition.

Participants were then prepared for taking performing a graded exercise test on the laboratory cycle ergometer. The test began with a warm up, and the difficult was ramped (25 W/min) until the subject reached volitional exhaustion. The pulmonary gas data was gathered via a calibrated parvomedic cart. The data was recorded for research purposes and collected into an excel sheet. While the participants were performing their test, they received motivational feedback in attempt to push them to keep going. Ratings of perceived exertion (RPE) was also recorded during this period. Data recorded was subject but not limited to VO_2, heart rate (HR), RER.

Exercise Protocols

Before performing the randomized protocol, the participants performed a three-minute warmup at 20% work rate max. There were two regimens put together for the study. One was moderate-intensity exercise (MIE), and one was a variable-intensity exercise (VIE). The two experimental conditions were randomized and performed on separate days in the fasted state. Both conditions began with a 15-min seated rest, followed by the assigned exercise. MIE consisted of continuous moderate-intensity exercise at 40% of maximal work rate (WRmax). VIE consisted of sixteen 10-sec supramaximal sprints (120% WRmax), sixteen 20-sec high intensity bouts (60% WRmax) and low-intensity recovery (20% WRmax) interspersed throughout the exercise. Total duration and total work were matched between conditions. Figure 1 shows both exercise bouts.

Figure 1. Exercise bout where the percent of work rate max is shown in the two protocols over time. MIE vs VIE



VIE= Variable Intensity vs Moderate. A total of 30 minutes of exercise was performed at a certain percentage of the subject's work-rate max.

Physiological Measures

While performing the exercise various physiological measures were taken as a part of the data collection. HR was connected to the parvomedic cart and was recorded via an attachable chest monitor, VO_2 was recorded with the parvomedics gas exchange ability, as well as RER. These measurements were recorded the entire time the exercise was performed and post exercise with few small breaks included for the subject's comfort.

Perceptual Measures

Prior to exercise commencing, participants became familiar with the usage of a perceived exertion scale with 0 being no activity and 10 being the hardest amount of exercise was being performed (23). This was recorded in 3-minute intervals during each session and was used in comparison for the other tests. The feelings scale was used so participants could rate their current affect, on a scale of -5 to +5. +5 meaning that they found the exercise to be very pleasant, -5 meaning it was not pleasant at all (24). Affect was recorded every 3 minutes during exercise. As well as a PACES form was filled out after the exercise that included multiple statements about how the person perceived the exercise that they had performed. PACES scales are a multiple-item assessment of enjoyment during a type of physical activity and have been concluded to be an acceptable measure of consistency and reliability for measuring enjoyment in younger adults (25). Finally, once the subjects had completed all protocols, they could rank the regimens in the order in which they enjoyed the most, and in the order in which they felt like they would actually do during their own exercise time.

Post-Exercise Measurements

After each protocol was performed, the subjects were required to rest for a sum of 75 minutes. During this time the three physiological measurements and most of the perceptual measurements were still being recorded as a part of the necessary data. Although 75 minutes may seem to be an unreasonable time, the subjects were given breaks were they were allowed to take the parvomedic masks off for up to 5 minutes. This was for rehydration, and comfortability purposes. These measurements were used to compare the protocols effect on the post exercise recovery period. The changes in fuel utilization pattern during recovery was a main part of conducting the study.

Results

Subject Characteristics

Shown in Table 1. Healthy young adults, both men (*n*=7) and women (*n*=3) were recruited as a part of the study. Recorded data includes VO_2max, WRmax, body mass index (BMI), and body fat percentage.

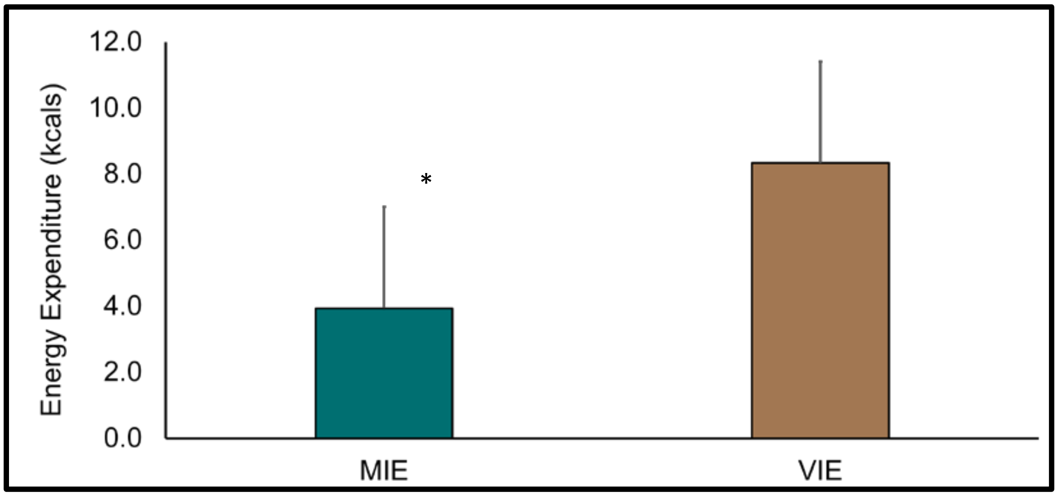
n	Age (yrs)	Height (cm)	Weight (kg)	Body Mass Index	Body Fat (%)	VO_2 max (ml·kg^{-1} ·min^{-1})	WRmax (W)
10 M=7 F=3	24.5 ± 5.2	173.3 ± 6.5	75.6 ± 11.0	25.1 ± 3.1	22.3 ± 7.8	35.0 ± 7.0	242.4 ± 53.3

Table 1. Participant demographics and physical measurements. Data presented as mean ± SD.

Energy Expenditure during Recovery

Figure 2 shows the energy expenditure during recovery was significantly different between the two groups. The MIE expended less kcals during recovery, when compared to the VIE protocol.

Figure 2. Energy expenditure in calories in both protocols MIE vs VIE

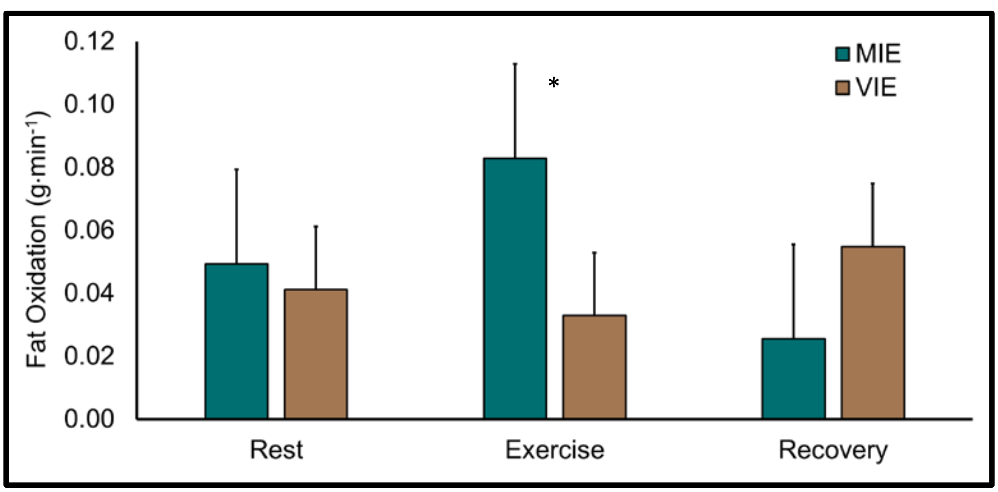


Data presented as mean ± SD. * = different from VIE ($p < 0.05$)

Fat Oxidation during Recovery

Figure 3 shows fat oxidation during recovery. There was an interaction between group and time, post hoc testing was performed to determine specifics differences. While during the rest and recovery portion there was no differences, there was a significant difference between the groups during exercise.

Figure 3. Change in fat oxidation during three phases- rest, exercise, and recovery



Data presented as mean ± SD. * = different from VIE ($p < 0.05$)

NET VO_2 during Exercise and Recovery

Figure 4 shows NET VO_2 during exercise and recovery. There was an interaction between group and time, post hoc testing was performed to determine specifics differences. NET VO_2 of MIE was significantly different during exercise from VIE. During the time intervals during rest 15, 30, 45, 60, and 75 minutes there was no difference.

Figure 4. Change in NET VO_2 during exercise and recovery intervals

Data presented as mean ± SD. * = different from VIE (p < 0.05)

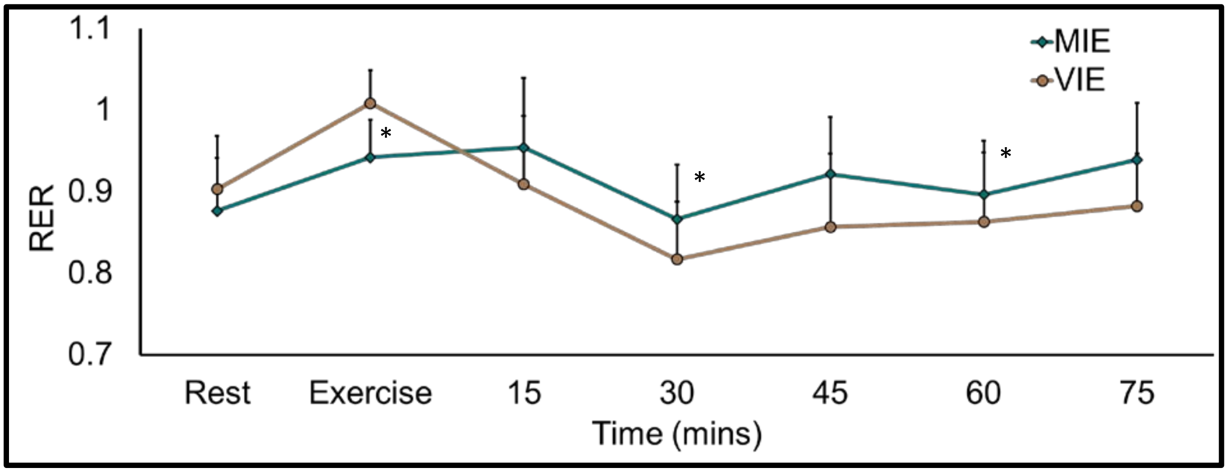
	Exercise	15 min	30 min	45 min	60 min	75 min
MIE	1.71 * ± 0.96	0.02 ± 0.02	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
VIE	1.21 ± 0.19	0.03 ± 0.04	0.02 ± 0.02	0.02 ± 0.02	0.02 ± 0.02	0.03 ± 0.02

Data presented as mean ± SD. * = different from VIE ($p < 0.05$)

RER during Rest, Exercise and Recovery

Figure 5 shows respiratory exchange ration throughout a trial. There was an interaction between group and time, post hoc testing was performed to determine specifics differences. RER was significantly different in several portions of the entire protocol. During exercise VIE was less than MIE, it was also significantly different during recovery at 45 minutes, and at 75 minutes.

Figure 5. RER in during exercise and recovery

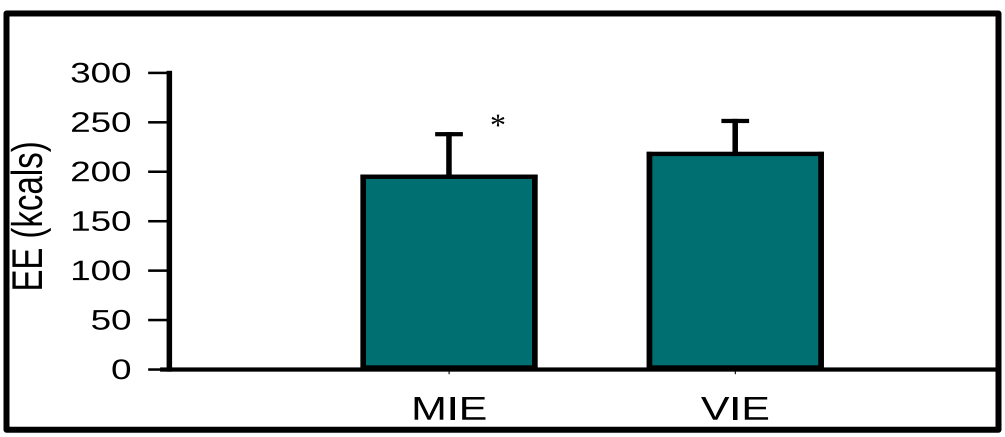


Data presented as mean ± SD. * = different from VIE ($p < 0.05$)

Energy Expenditure during Exercise

Figure 6 shows energy expenditure during MIE and VIE. There was a significant difference between the two protocols where VIE was higher than the MIE protocol.

Figure 6. Total energy expenditure during exercise



Data presented as mean ± SD. * = different from VIE ($p < 0.05$)

Perceptual Responses

Figure 7 shows the perceptual responses, including RPE, Affect, and PACES. There was a significant difference between RPE where MIE was less than VIE. While there were no differences between Affect, and PACES.

Figure 7. Perceptual responses in both protocols.

	RPE	Affect	PACES
MIE	3.23* ± 1.18	2.46 ± 1.22	82.6 ± 12.3
VIE	4.32 ± 1.14	2.21 ± 0.99	89.9 ± 8.1

Data presented as mean ± SD. * = different from VIE ($p < 0.05$)

Discussion

This study was conducted to compare the metabolic and perceptual responses occurring in the body during two different exercise protocols. The metabolic responses including fat oxidation, VO_2, RER, and energy expenditure. Perceptual responses were to determine whether one exercise was preferred over the other, and to see how people felt about both protocols. The perceptual responses recorded included a PACES scale, Affect, and RPE.

The study showed that the energy expenditure was different between protocols. During the VIE protocol, participants expended more energy than the MIE. In combination of exercise and recovery a total of about 27 calories more calories were expended in the VIE protocol. However, 27 calories may not seem to be a huge difference, as this is about ½ a cup of mixed berries. Fat oxidation was only different during the exercise portion of the trial. In general, the lower the intensity of exercise the greater the rate of fat oxidation, this is because fat will take longer to metabolize into energy (10). While the higher the intensity of exercise, the body would resort to using more carbohydrates. This was somewhat expected because the energy demand during the MIE protocol is a lower intensity, leaning towards using some fat when compared to the VIE where more carbohydrates would be used as an immediate energy source. NET VO_2 being different during exercise is expected as well because the oxygen demand during the higher intensity portions of the VIE protocol is greater. RER differences seen during the exercise portion, and at the 30 minute, and 60 minute interval. The difference during the exercise was expected because of the higher energy demand of the VIE protocol, thus more carbohydrates would be used during exercise (6). Therefore, during recovery the body would use more fat because of its availability and lower energy demand. However, the differences during the 30- and 60-minute intervals were not hypothesized. These differences may have been due to the lactic acid buffering period the body goes through during recovery, which increases CO2 production (26). This would increase RER independent of fuel use, but studies have shown that CO2 production returns to metabolic levels by 75 minutes. Another reason for RER to be altered is for the differences in fuel use during exercise and recovery. During high intensity exercise the RER would be greater, because of the greater usage of CHO, where the lower the intensity exercisers the body would use more fats therefore a lower RER (10). Then during recovery, the high intensity exerciser would have more fats available making a lower RER, where the lower intensity would have a higher RER due to using more available CHO (27).

In comparison to other research, a lot of previous research has focused on the differences in VO_2, HR, and blood lactate concentration. In one study, the VO_2 differences shown between a moderate protocol and high intensity interval protocol showed that the overall VO_2 was greater throughout the session. In comparison to ours where the VO_2 and NET VO_2 were higher in the VIE protocol versus the moderate (26). Another portion researched was energy expenditure where in the study the moderate exercise expended more calories, where in our research the VIE expended more during recovery. The most similar research was found in terms of the perceptual ratings of the protocols. RPE, Affect, and on a PACES scale were taken and recorded to see the difference. The RPE in one study was seen to be less in a moderate protocol compared to a high intensity protocol which was similar to our results. The PACES scale was not significantly different which was also similar to our results. The affect was more positive in the moderate intensity protocol which was not the same as our study, where the VIE and MIE protocols were similar (26). The lack of differences in the present study suggests that people responded similarly to the MIE and potentially would enjoy it better than HIIT.

The practical application of these results is that it gives exercisers another aerobic routine they can try. The similarities in the metabolic responses of the two protocols show that variable intensity exercise could also get similar health benefits that traditional moderate exercise routines can give. In terms of the metabolic responses, the VIE did show that more calories were able to be expended during exercise and recovery. A total of about 27 calories over each exercise bout for five days a week is a total amount of 150 calories. Some exercises interested in expending more energy and weight loss could use this protocol to get more out of their aerobic exercise. As the ACSM recommends about 150 minutes of exercise per week, the VIE protocol which showed similar metabolic responses to the MIE protocol could be done as a part of the 150 minutes of exercise (2, 28). The one significant difference was in the RPE scale. Those performing the VIE protocol had a greater average rate of perceived exertion. There were no differences in the perceptual responses of affect or in enjoyment via PACES. Meaning that while participants performed the same amount of total work, and the VIE felt harder to participants, participants enjoyed both protocols the similarly. This showed that while performing the protocol the subjects thought they were working harder, and for some this may be more gratifying.

One of the limitations of our study was the number of subjects. A total of 10 subjects and the population of young adults in the study, the same results may not be applicable to older populations. The difficulty of recruiting subjects may be due to bad experience with exercise, or the time commitment of the three sessions. Another limitation is the recovery period. While it was a total of 75 minutes, this may not have been long enough for subjects to fully recover, and important recovery data could have been missed out on (29). For example, during the recovery portion the mask was taken off for several 5 minutes breaks. This could affect the averages of that data that was taken during the recovery portion. However, this was deemed necessary for rehydration and for comfort. VO_2 was similar at rest at the end of each recovery and fuel use has been shown to be valid after 75 minutes of high intensity exercise (29). Some other limitations include that the researchers did not have control or able to measure if a person came in a fully fasted state, and their current diet was not considered. However, all participants were instructed to fast for 12-hours. Research has shown that a 12-hour fast can control for a standard diet (28). This could have affected measurements like RER or fat oxidation.

For future research, there are several things that may be added to get more insightful responses. One being an even longer recovery period to continue the tracking of metabolic responses. Another being adding in a verification trial for VO_2max because it was noticed that some subjects were able to go over their initial max during the VIE protocol (30). If a subject did not reach their max this means they will be exercising at a lower intensity when compared to other subjects and then effect fuel use during exercise and recovery (6). A high intensity interval bout was also done and could be tweaked. High intensity exercise does have some negative aspects to it, including more chance for injury, subjects may not enjoy it as much, and it may be at a pace that is hard to keep up with for the average exerciser (26). The VIE was done because it is a good balance between high and moderate intensity. VIE is able to have points at high intensity so you feel like you are working hard, but there are some breaks that can be relieving. Another trial of these protocols could be done to see differences in recovery if the subjects could eat a controlled meal, which would make the results more applicable to normal exercise training. The transition to children was also an initial interest. However, it may even be harder to recruit children for a study like due to the fasting involved, the high intensity workout, and the long recovery period. Nonetheless, the difference in metabolic response in children during both exercise and recovery would be interesting to delve into considering there is not previous research involved.

Conclusion

The purpose of this study was to look at metabolic responses and enjoyment during two exercise protocols. The comparison to moderate intensity showed not only similar metabolic results, but similar perceptual results. Where the VIE protocol expended more energy during exercise and recovery, it had a lower fat oxidation during exercise, and a lower VO_2 during exercise in comparison to the MIE protocol. As well as the RER in the VIE was higher during exercise, but significantly lower during portions of the recovery period. While at the same time the subjects felt like they were working harder but enjoyed both protocols similarly. Thus, VIE is another option for people to maintain ACSM standards for aerobic exercise. If someone was interested in losing weight, exercising at a higher intensity, and overall enjoying the exercise the same way they do moderate intensity, VIE is a good routine for them.

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