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Physiological and Perceptual Responses to Various Types of Exercise

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By

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Abstract

Previously, we found that variable-intensity exercise (VIIE) was more enjoyable than high-intensity interval exercise (HIIT), but the physiological stress was reduced. This study will examine exercise intensity, energy expenditure (EE), and perceptual responses during and after moderate-intensity exercise (MIE), HIIT, and VIIE. On separate days, the three work-matched bouts of exercise (MIE, HIIT, & VIIE) were randomized and performed. Oxygen consumption, heart rate (HR), and muscle oxygenation were collected over the entire bout for all conditions. OMNI ratings of perceived exertion (RPE) and affect, via Feelings Scale, were measured in-exercise and enjoyment was measured post-exercise using the physical activity enjoyment scale. The high and varied intensity of VIIE may elicit a similar or higher EE and be perceived as more enjoyable and improve affect compared to HIIT and MIE. The similar or greater responses to VIIE may present as a new alternative exercise format and increase adherence to training.

Keywords: High-Intensity Interval Training, Variable-Intensity, Enjoyment, Affective Responses, Physiological Stress, Exercise

Introduction

Regular participation in physical activity and exercise has been shown to be associated with many physiological and psychological benefits and improvements to overall quality of life. The American College of Sports Medicine (ACSM) recommends that adults participate in cardiorespiratory exercise for at least 150 minutes per week at a moderate-intensity (46-63% of aerobic capacity) or 75 minutes per week at a vigorous-intensity, or an energy-equivalent combination of moderate to vigorous intensity exercise to obtain maximal health benefits (American College of Sports Medicine, 2018). Currently, there is no optimal approach to reach the ACSM's physical activity recommendations for health and fitness. A popular form of training is moderate intensity exercise (MIE), which involves exercising continuously at a moderate, steady-state intensity. While many people do enjoy MIE, several complaints of this type of training are that it is perceived as boring and/or monotonous and is time-consuming to reach the desired energy expenditure (EE) (Bartlett et al., 2011; Swain, 2005).

Background

Recently, researchers have explored a more vigorous type of exercise known as high-intensity interval training, or HIIT, which is a form of training alternates bouts of high intensity work with low intensity recovery. HIIT has shown to provide similar improvements in health and aerobic fitness when compared to MIE. Multiple studies have found that HIIT elicits increased physiological responses such as higher average oxygen consumption (VO_2), peak VO_2, and % heart rate max (%HR_{max}) (Karlsen et al., 2017; MacInnis & Gibala, 2017; Olney et al., 2017). Since HIIT induces greater physiological stress on the body than MIE, a single session of HIIT can be completed in a shorter amount of time while eliciting similar or greater physiological

adaptations (Helgerud et al., 2007; Karlsen et al., 2017; Olney et al., 2017; Stork et al., 2018). A drawback of HIIT is that due to the alternating high and low intensity as well as the shorter duration, total EE during exercise is lower as compared to MIE (Schaun et al., 2018; Skelly et al., 2014).

Although HIIT elicits similar or greater physiological benefits in a shorter amount of time than MIE, the perceptual responses of the participant must also be taken into consideration. Perceptual responses, such as affect, enjoyment, and rating of perceived exertion (RPE), are important to consider because of their associations with exercise adherence (Rhodes et al., 2009; Williams, 2008). Affect is the positive or negative emotional response that an exercise evokes. If an exercise makes the participant feel bad or in pain, adherence will be lowered. Enjoyment is similar to affect in that if a subject perceives an exercise to be unenjoyable or disinteresting, they will not have a desire to participate in that exercise again (Kilpatrick et al., 2014). RPE is the subjective evaluation of how hard the participant feels that they are exerting.

A downside of HIIT is that affect was found to be significantly lower than MIE, however, enjoyment was similar among the two training programs (Bartlett et al., 2011; Olney et al., 2017; Stork et al., 2018). Decreased affective responses have been shown to be associated with exercise intensities that are above the anaerobic threshold, such as HIIT (Ekkekakis et al., 2011; Oliveira et al., 2018). RPE was found to be higher in HIIT than in MIE (Olney et al., 2017; Sagelv et al., 2019; Thum et al., 2017). It is likely that the higher physiological responses and lower perceived affective response are most likely caused by the higher intensity of HIIT. Despite the time efficiency and physiological benefits, it is possible that the lower affective response to exercise could result in lower adherence to HIIT (Kilpatrick et al., 2014; Stork et al., 2017).

Variable-intensity interval exercise (VIIE) may be an alternative training option to help meet the ACSM's physical activity recommendations. VIIE involves several bursts at supramaximal intensities for a very short time and at near-maximal intensities for a longer amount of time, as well as low-intensity recovery periods that are frequently interspersed between the bursts of higher intensities. VIIE is similar to HIIT with alternating bouts of higher and lower intensities, however the work rates are near-maximal and supramaximal and tend to be shorter in duration than the intervals performed during HIIT. A previous study by Thompson et al. (2019) found that the varying vigorous intensities were perceived as more enjoyable and reported higher affective responses and elicited a greater EE during exercise as compared to HIIT. However, the physiological responses such as VO_2 and HR were greater in HIIT. Further research is needed to determine if a VIIE protocol could produce physiological responses similar to HIIT while still eliciting positive perceptual responses.

Purpose and Hypotheses

The purpose of this study was to examine the physiological and perceptual responses during and after work-matched MIE, HIIT, and VIIE in healthy men and women. The physiological responses of HR, VO_2, and EE were studied and compared between all three protocols. The psychological responses of RPE, affect, and enjoyment were also recorded to examine the subjective feelings toward the exercise being performed.

Hypotheses

1. It was hypothesized that VO_2 and HR would be similar between VIIE and HIIT. The mixture of supramaximal and higher near-maximal bursts of intensity during VIIE will average similar amounts of physiological stress as the slightly lower near-maximal bursts

of intensity during HIIT. VIIE and HIIT would greater than MIE because of the bursts of higher work rates in VIIE and HIIT.

2. RPE will be highest during VIIE, followed by HIIT, and lowest during MIE. It will be highest during VIIE due to the supramaximal and near-maximal work rates, whereas HIIT is only near-maximal and MIE is much lower intensity.
3. From rest, affect will decrease the most during HIIT, followed by VIIE, and will decrease the least during MIE. The work rate of MIE is not usually above the anaerobic threshold whereas VIIE and HIIT are. However, VIIE has more recovery periods with less time at work rates that are above the anaerobic threshold so affect will still decrease, but it will decrease less than HIIT.
4. Post-exercise enjoyment will be highest for VIIE. It will be slightly lower for HIIT and the lowest for MIE. The alternating intervals of VIIE and HIIT will be perceived as less boring than MIE. VIE will be more enjoyable than HIIT because the varied work rates will be stimulating and will absorb the subjects in the activity.

Significance

The main interest of this research is to determine if VIIE is a viable alternative to HIIT or MIE in adults. The VIIE protocol aims to combine the advantages of the physiological stress of HIIT and the affective response to MIE, all while being time efficient and enjoyable. Achieving higher physiological responses as well as higher enjoyment and affective responses is key to not only maximizing health benefits, but also increasing adherence to exercise.

Literature Review

Introduction

The contents of this review intend to cover the acute physiological responses, psychological measurements, and benefits of exercise in regard to the American College of Sports Medicine's recommendations for physical activity. The health benefits and physiological and psychological responses to high intensity interval training will be explored. Comparisons in responses to high-intensity interval training and continuous moderate-intensity exercise will be used to determine the overall efficacy of variable intensity interval exercise as a training regimen.

Acute Physiology During Exercise

VO_2 rises linearly as exercise intensity increases because of the enhanced need for oxygen in the muscles and tissues (Hickson et al., 1978; McInnis et al., 1996). Along with this, HR, blood pressure, and stroke volume must increase in order to be able to deliver oxygenated blood to the muscles and tissues to allow exercise to increase. The increased stress and deoxygenation of skeletal muscles causes the need for increased delivery of oxygen to the muscles and a rise in cardiac output, arterial-venous O_2 difference, and muscle blood flow. Adaptations of the body are required in order to the demands of the exercise being performed (Nioka et al., 1998).

EE rises as exercise intensity and duration increases. Multiple studies have found that EE was higher in MIE than HIIT due to the greater volume of exercise being performed (Olney et al., 2017; Schaun et al., 2018). In order to produce similar amounts of EE, either the work rate or duration of HIIT must increase.

Acute Psychological Measurements

Affect is a psychological response regarding how one feels toward a specific activity or situation. The Feeling Scale (FS) uses a numerical scale to gauge positive, negative, and neutral responses to activity (Hardy & Rejeski, 1989). In this context, it is a subjective measure of a participant's outlook regarding an exercise protocol. While affect is usually recorded during exercise, enjoyment is measured post-exercise. Enjoyment is the emotions evoked during an activity and can be measured using the Physical Activity Enjoyment Scale (PACES). The PACES scale has participants' rate 18 bipolar items on a 1-7 scale. This numerical scale is important in discovering if an activity was pleasurable or not or if it elicited undesirable emotion (Kilpatrick et al., 2014; Plante et al., 2018). The Borg rating of perceived exertion scale rates physical effort on a scale of 6 to 20 that corresponds to levels of exertion ranging from no exertion at all to maximal exertion (Borg, 1998).

Chronic Benefits of Exercise

Currently, physical activity guidelines recommend either 150 minutes of moderate-intensity exercise or 75 minutes of vigorous-intensity exercise, or an energy-equivalent combination of the two intensities in order to obtain maximum health benefits (American College of Sports Medicine, 2018). Meeting these recommendations stimulates chronic physiological and psychological benefits for the body and has been shown to increase aerobic fitness, reduce risk of disease, and improve body composition and overall health (Ciomag & Zamfir, 2016).

Aerobic fitness is a measure of how oxygen is transported and used in the body in order to produce movement and is most accurately measured by the maximum oxygen uptake during

graded exercise (VO_2max). Training at a higher intensity can improve the capacity for aerobic fitness (Rejc et al., 2017). Participating in aerobic exercise lowers the risk for cardiovascular-related diseases, such as hypertension, dyslipidemia, and diabetes (Rejc et al., 2017). Partaking in regular exercise initiates chronic cardiovascular adaptations so the heart and body become accustomed to the stress and cultivate the extensive health benefits such as elevated high-density lipoproteins, improved insulin sensitivity, and reduced resting blood pressure (Nystoriak & Bhatnagar, 2018). A study by Foulds et al. (2014) found that a dose-response relationship between exercise intensity and health benefits. Increasing intensity reaped greater benefits such as improvements in VO_2max, maximal aerobic power, and body mass status than at lower rates. Greater aerobic fitness and lower body mass correlate to a reduction in risk for all-cause mortality .

High-Intensity Interval Training

High-intensity interval training, commonly known as HIIT, involves alternating bouts of higher intensity exercise and lower intensity recovery or rest. In general, HIIT can be classified as aerobic HIIT or resistance HIIT, depending on the mode of exercise chosen to be performed. Aerobic HIIT typically utilizes activities such as running or cycling whereas resistance HIIT may use weights, plyometrics, and body weight activities to achieve the periods of high and low intensity (Kilpatrick et al., 2014). Another higher-intensity variation of HIIT is known as sprint interval training (SIT), which involves short intervals performed at maximal or supramaximal intensities that produce at or near VO_{2peak} values (MacInnis & Gibala, 2017). There are endless combinations of intensity and interval duration to create a HIIT/SIT regimen, therefore making comparisons between studies can be difficult. However, many studies that implemented

different protocols yielded similar results regarding acute physiological responses (Brown et al., 2018; da Silva Machado et al., 2019; Follador et al., 2018; Helgerud et al., 2007; MacInnis & Gibala, 2017).

Since HIIT is performed at much higher intensities than continuous moderate-intensity exercise (MIE), it can be done for a shorter duration and still produce desirable physiological responses. In research comparing MIE to HIIT, HIIT has demonstrated to elicit physiological responses such as a higher VO_2 and $\%HR_{max}$ (Helgerud et al., 2007; Olney et al., 2017). The higher intensity of HIIT allows participants to exercise for a shorter amount of time and still achieve the same, or greater, physiological responses as MIE.

The specific mode of HIIT influences which systems benefit the most from training, but in general HIIT has shown to improve aerobic capacity, insulin sensitivity, and blood pressure as well as reduce risk for cardiovascular disease and all-cause mortality (Karlsen et al., 2017; Kilpatrick et al., 2014; MacInnis & Gibala, 2017). A 2018 study implemented a multimodal HIIT regimen and found a significant decrease in total body fat percentage as well as significant increases in bone mineral content and muscular and cardiovascular fitness (Brown et al., 2018).

While HIIT has been shown to elicit similar, and often greater, physiological benefits than MIE, adherence remains an issue. Affect is an important driving factor in participants' reliability to continue training (Kilpatrick et al., 2014; Stork et al., 2017; Williams, 2008). Psychologically, some studies found that affect was significantly lower in HIIT than MIE, but overall evoked similar enjoyment between programs (Olney et al., 2017; Stork et al., 2018; Thum et al., 2017). The alternating intervals and rest periods used in HIIT are shown to be perceived as favorable over continuous exercise (Kilpatrick et al., 2014; Thum et al., 2017). In a

study by Sagelv et al (2019) exercise enjoyment responses were recorded as similar between HIIT and MIE even when longer interval sets of 4 minutes were used. Although affect was found to be lower during HIIT compared to MIE, similar post-exercise enjoyment levels and higher physiological responses establish HIIT as a beneficial form of training that will maintain participant adherence.

Variable-Intensity Interval Exercise

Variable-intensity interval exercise (VIIE) is a training protocol that may be a desirable alternative to HIIT and MIE. VIIE is similar to HIIT in that it alternates intervals of high intensity with rest periods, however the intervals are not the same intensity for each bout (Kilpatrick et al., 2014). The varying bursts of maximal or supramaximal intensities and the intervening lower-intensity rest periods are performed for relatively short durations. The quick changing between bursts and recovery periods allow participants to work above and below the anaerobic threshold as opposed to HIIT which is mainly above the threshold. Exercising for a shorter duration above the anaerobic threshold may improve affective responses (Ekkekakis et al., 2011). The alternating of high-intensity bursts and recovery periods during VIIE may be perceived as more engaging than continuous MIE.

A previous study by Thompson et al. (2019) compared the physiological and perceptual responses of VIIE, HIIT, and MIE. In this study HIIT was the shortest duration, but VO_2 and HR were highest during this exercise bout as compared to VIIE and MIE. Despite the slightly longer duration and lower physiological responses, total EE was higher in VIIE than HIIT. This study also found that there were no significant differences in affective responses between trials, however HIIT had the most negative change in affect from rest. VIIE was found to be most

enjoyable post-exercise with little difference between HIIT and MIE enjoyment. Overall, VIIE may evoke acute physiological responses similar to that of HIIT but may be perceived as more enjoyable and increase affect as compared to HIIT and MIE.

Methods

Experimental Outlines for the Study

All sessions were performed in an exercise physiology laboratory that maintained a stable temperature and barometric pressure. The subjects were asked to come into the laboratory for a total of four sessions. The first visit was for familiarization and baseline measurements and the following three visits were for each of the experimental trials. The experimental trials were matched for work rate and the exercise bouts were performed in a randomized order. Subjects were asked to avoid vigorous exercise for at least 24 hours before testing and to avoid consumption of caffeine, alcohol, and tobacco for at least 10 hours prior to testing.

Subjects

Healthy recreationally active adults were recruited to participate in this study. This study was approved by the university institutional review board prior to conducting the study.

Visit 1

During the initial visit, informed consent and a health history questionnaire were completed. The participants' height and weight were taken using a stadiometer and calibrated scale, respectively. Body composition was measured using a fully calibrated Bod Pod. After baseline measurements were taken, subjects were familiarized with the equipment as well as the Borg rating of perceived exertion scale, Hardy and Rejeski's Feeling Scale, and the Physical Activity Enjoyment Scale (PACES). The subjects were then asked to perform a ramped graded exercise test on an electronically-braked cycle ergometer to determine their individual VO_2max. The test began with a four-minute warmup at 20 watts and then increased continuously at a

rate of 25 watts per minute until the subject reached volitional exhaustion. Pulmonary gas exchange was measured breath by breath using a calibrated COSMED Quark CPET metabolic cart. Expired air was collected through a face mask and averaged every 15 seconds. The subject's heart rate was continuously recorded throughout the test using a Polar chest-strap heart rate monitor. Subjects received motivational feedback and encouragement while performing the test. Data recorded included VO_2 and maximal work rate (WR_{max}). The highest values achieved during the test were considered to be maximal.

Visits 2, 3, and 4

Each visit began with a 15-minute rest period, followed by one of the three exercise protocols, and then another 15-minute recovery period. Subjects followed the same procedures for all of the three visits, except the exercise protocol performed was randomized and different for each visit. At the end of the 15-minute rest period, subjects were asked what their affective score was on the Feeling Scale. Each of the three exercise protocols began with a 3-minute warm up and finished with a 3-minute cool down at 20% of the individual's WR_{max}.

The MIE protocol consisted of 30 minutes of continuous stead-state exercise at 34% of each subject's WR_{max}. The total time spent exercising during this bout was 36 minutes. The VIIE protocol consisted of a 3-minute pattern that follows: 10 seconds at 140% WR_{max}, 15 seconds at 20%, 30 seconds at 80%, 50 seconds at 20%, 10 seconds at 140%, 15 seconds at 20%, 30 seconds at 80%, and 20 seconds at 20%. This 3-minute pattern was repeated three times for a total of 9 minutes and then was followed by a 3-minute active rest at 20% WR_{max}. The participant then completed the 3-minute pattern another three times. The total time spent exercising during the VIIE bout was 27 minutes. The HIIT protocol consisted of alternating

intervals of 1 minute at 20% WR_{max} and 2 minutes at 70% WR_{max}. Subjects completed 9 minutes of alternating intervals followed by a 3-minute active rest at 20% WR_{max} and then another 9 minutes of intervals. The total time spent exercising during the HIIT bout was 27 minutes. The three exercise protocols are shown in Figure 1.

VO2, HR, and RER were recorded throughout the entire exercise session for all three protocols. Subjects were asked to report their RPE and affective score every 3 minutes during exercise. At the end of the 15-minute post-exercise recovery period, subjects completed the PACES and reported their recovery affective score.

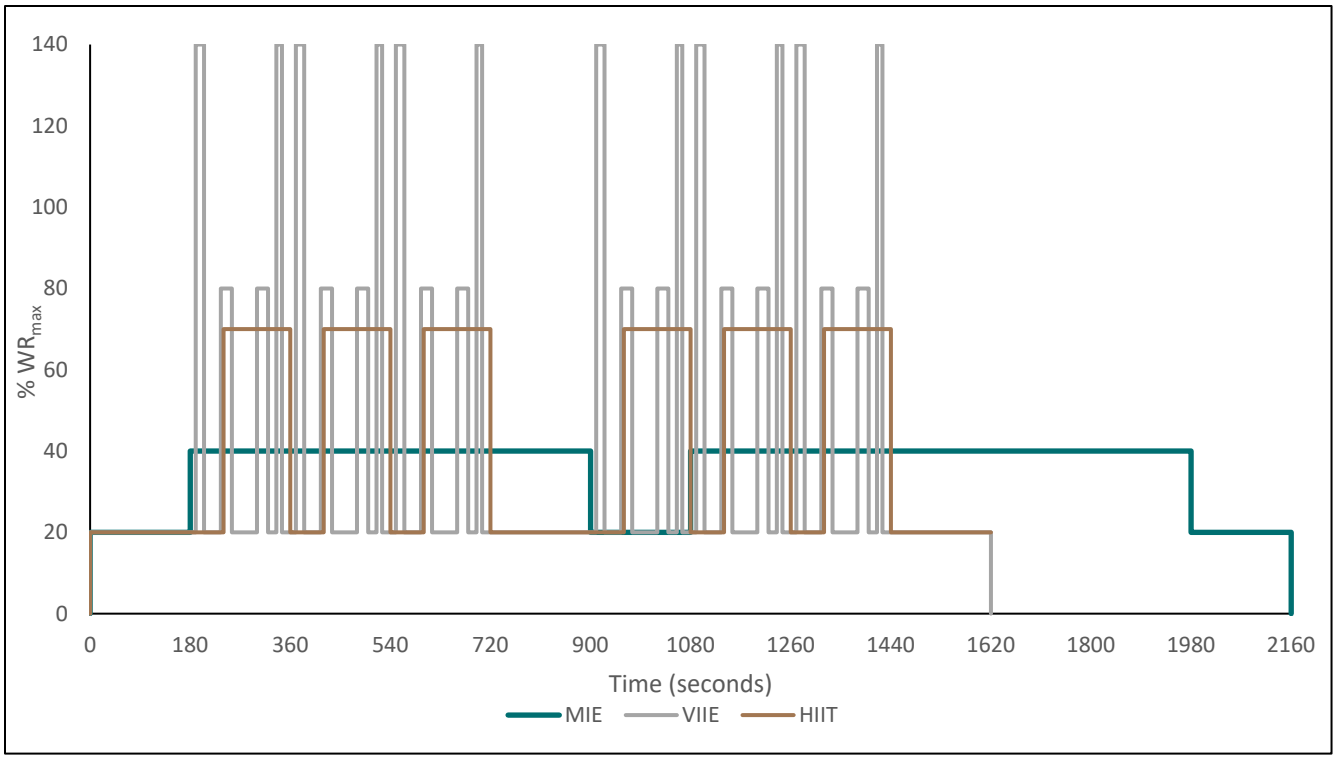

Figure 1. Bout pattern for the three exercise protocols.

Data Analysis

A two-way trial by time ANOVA was performed to compare VO_2, HR, RER, and RPE at 50% and 100% of exercise duration between MIE, HIIT, and VIIE. A two-way trial by time ANOVA was also used to compare affect at rest, 50% of exercise, 100% of exercise, and

recovery between the three protocols. A one-way ANOVA was used to compare enjoyment (PACES) between protocols. Subsequent post-hoc tests were run when necessary. Significance was established at $p<0.05$.

Results

Subject Characteristics

Seven healthy adults, both men (n=3) and women (n=4), were recruited as part of this study. Data recorded during the initial visit are shown in Table 1.

Table 1. Descriptive measurements and statistics of participants.

Age (years)	Height (cm)	Weight (kg)	Body Mass Index
27.79 ± 6.12	171.59 ± 7.36	74.66 ± 11.68	25.46 ± 4.47

Data presented as mean ± SD.

Table 2. Maximal exercise responses

VO2max (mL/kg/min)	WRmax (Watts)	HRmax (bpm)	RERmax
32.80 ± 5.45	226.86 ± 39.87	186.14 ± 4.41	1.34 ± 0.11

Data presented as mean ± SD.

Physiological Responses

Figure 2 shows that VO_2 response was significantly higher in both HIIT and VIIE compared to MIE. There was also a significant difference in responses between HIIT and VIIE.

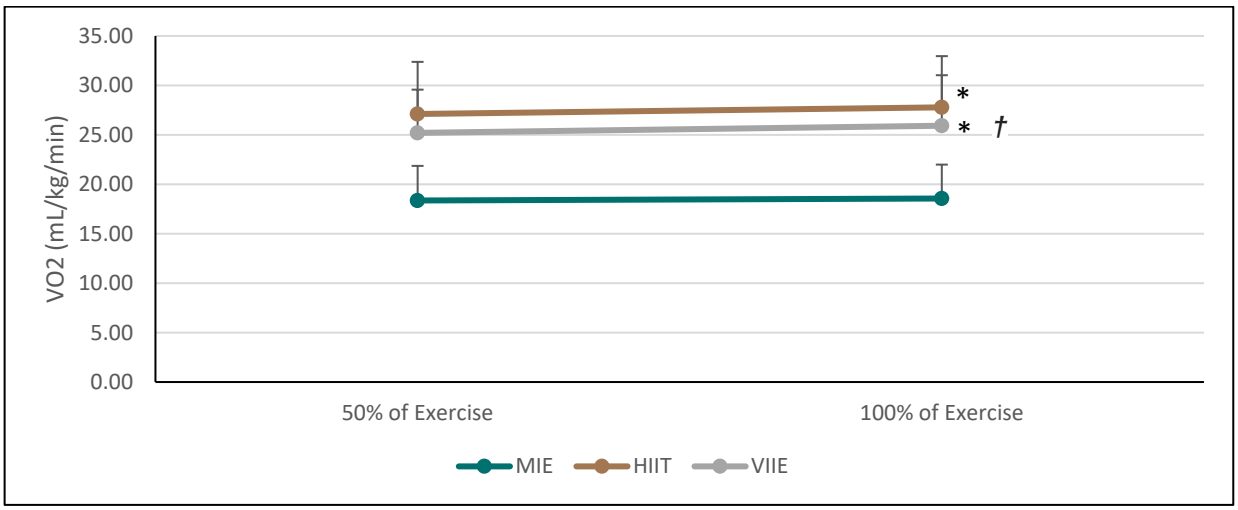

Figure 2. VO_2 response during exercise. Data presented as mean ± SD. * = significant difference from MIE (main effect of group). † = significant difference from HIIT (main effect of group).

Respiratory exchange ratio was significantly higher in both HIIT and VIIE compared to MIE. There was no significant difference in RER between HIIT and VIIE.

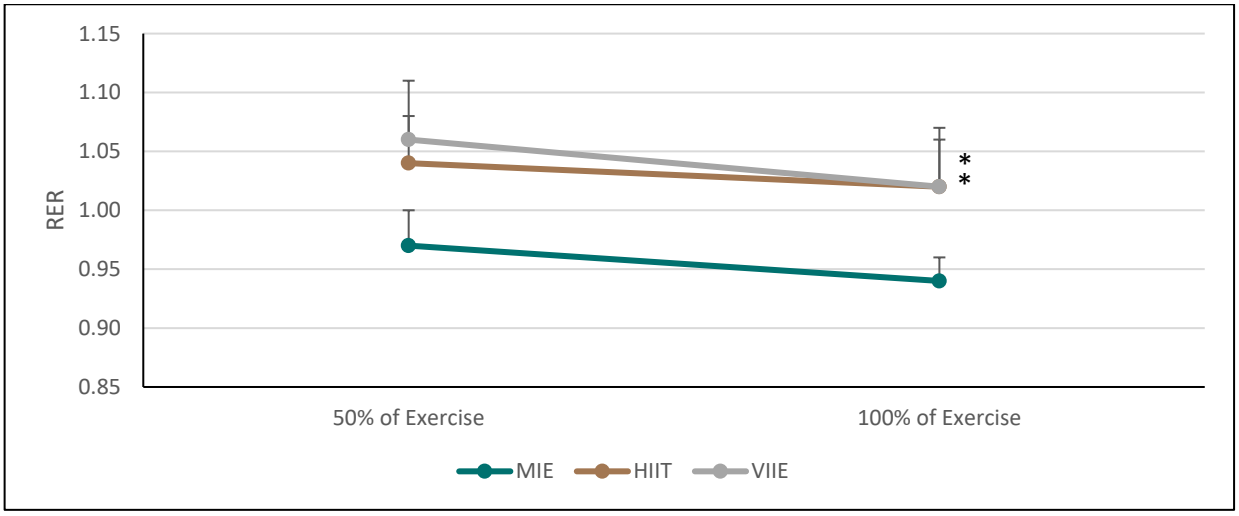

Figure 3. RER during exercise. Data presented as mean ± SD. * = significant difference from MIE (main effect of group).

Figure 4 shows that heart rate response during exercise was significantly higher in HIIT and VIIE compared to MIE. There was no significant difference in HR response between HIIT and VIIE.

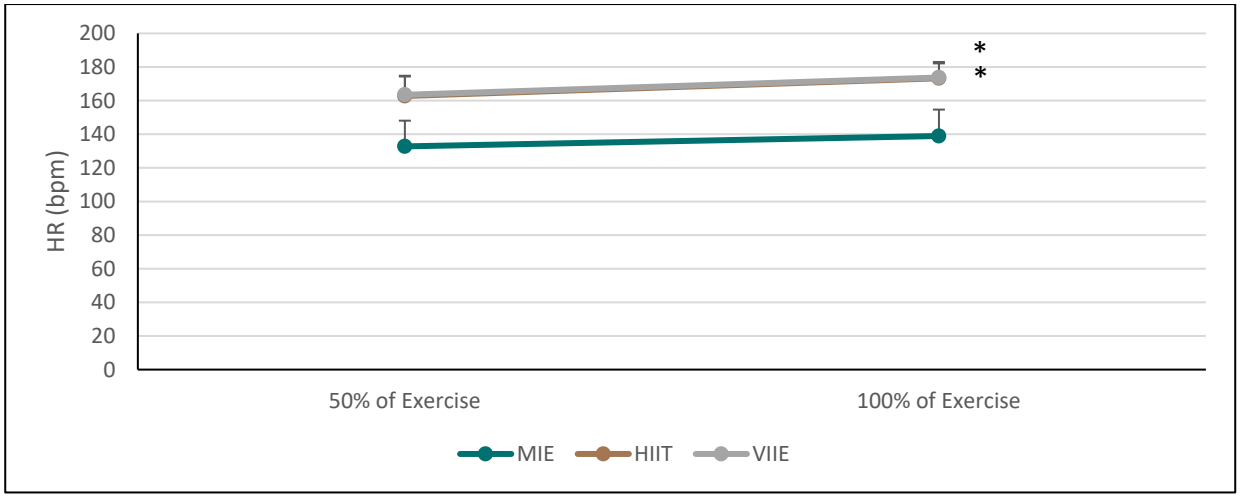

Figure 4. Heart rate response during exercise. Data presented as mean ± SD. * = significant difference from MIE (main effect of group).

Perceived Exertion and Enjoyment

Table 3 displays subject enjoyment recorded via the PACES, which was taken after exercise. Enjoyment was significantly higher in VIIE than HIIT, however there was no significant difference in either VIIE or HIIT compared to MIE.

Table 3. Enjoyment of MIE, HIIT, and VIIE via PACES.

MIE	HIIT	VIIE
79.86 ± 16.935	75.43 ± 9.947	88.29 † ± 6.075

Data presented as mean ± SD. † = significant difference from HIIT.

Figure 5 shows that perceived exertion, using the Borg Rating of Perceived Exertion scale, was significantly higher in both VIIE and HIIT compared to MIE.

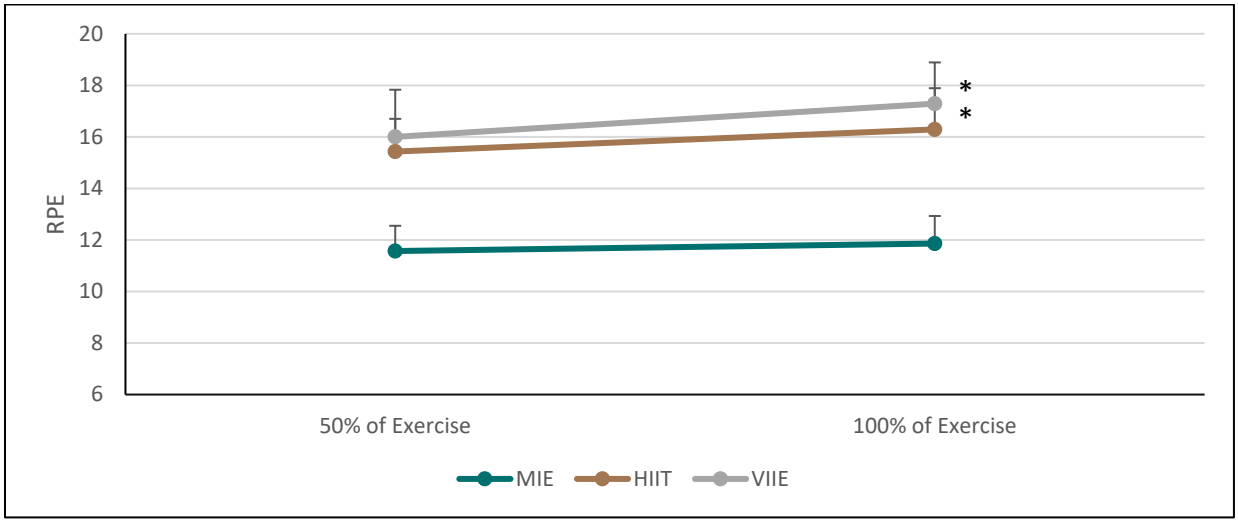

Figure 5. Rating of perceived exertion during exercise. * = significant difference from MIE (main effect of group).

Affect During Rest, Exercise, and Recovery

Figure 6 displays the change in affective responses from rest, halfway through the exercise bout, at the end of the exercise bout, and during recovery.

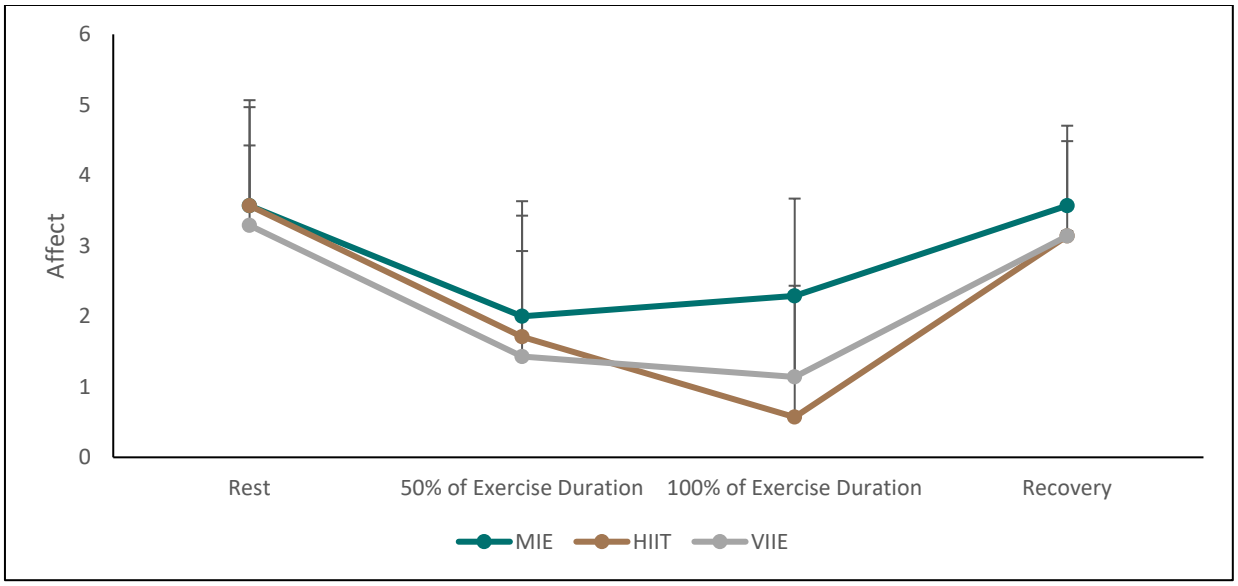

Figure 6. Affective responses during rest, exercise, and recovery. Data presented as mean ± SD.

Discussion

The present study compared the acute physiological and perceptual responses to MIE, HIIT, and VIIE. This study found that although VO_2 was significantly highest during HIIT, HR and RER were similar between HIIT and VIIE and both were significantly higher than MIE. RPE was also similar between HIIT and VIIE, but enjoyment was significantly higher in VIIE than HIIT. From rest, affect decreased the least during MIE compared to the other two trials, though not significantly.

The data from this study did not fully support the original hypothesis that VO_2 and HR would be similar during HIIT and VIIE, and both would be greater than MIE. The results for HR supported the hypothesis; VO_2 was found to be significantly higher during HIIT than the other two protocols, which did not support the hypothesis. VO_2 and HR were predicted to be lowest during MIE because although HIIT can vary widely in protocol, other studies comparing the physiological stress of HIIT versus MIE have also found that MIE elicited a significantly lower VO_2 and HR response than HIIT due to the overall lower intensity of exercise (Helgerud et al., 2007; Olney et al., 2017; Thum et al., 2017). Thompson et al. (2019) found that VO_2 and HR were higher in HIIT than both VIIE and MIE. However, the VIIE protocol used in that study used bursts at 120% and 60% WR_{max}, rather than the current protocol that has bursts at 140% and 80% WR_{max}. It was originally expected that VO_2 and HR would both be similar in HIIT and VIIE. Although the bursts were shorter in duration, the supramaximal and near-maximal work rates of VIIE was predicted to average similar physiological stress compared to lower work rates of HIIT. Although the HR responses of HIIT and VIIE show that both protocols are physiologically stressful, it can be concluded that the work rates did not average similar stress due to the

resulting higher VO_2 elicited during HIIT. Similar VO_2 responses between HIIT and VIIE may occur if either the duration of the high intensity bursts during HIIT are shortened, or the duration of the supramaximal and/or near-maximal bursts during VIIE are lengthened, although this assertion still needs to be studied.

While VO_2 was the highest during HIIT, there was no significant difference in RPE between HIIT and VIIE. Perceived exertion was significantly higher in both VIIE and HIIT compared to MIE, which is supported by many previous studies. It is understood that although there are low-intensity recovery periods during HIIT and VIIE, the overall higher work rates of those protocols will be perceived as more strenuous than the continuous moderate intensity of MIE (Bartlett et al., 2011; Olney et al., 2017; Sagelv et al., 2019; Stork et al., 2018). RPE was similar at 50% and 100% of exercise during VIIE and HIIT. This may have been because the higher intensity bursts at 80% and 140% of WR_{max} during VIIE were short enough to cause a similar feeling of exertion as the longer bursts of 70% WR_{max} during HIIT.

Affect decreased from rest in each of the protocols, with no significant difference in change between trials. This did not support the hypothesis that from rest, affect would decrease the least during MIE. Olney et al. (2017) found that affect was significantly higher at 50, 75, and 100% of exercise during MIE compared to HIIT and SIT. The higher intensities of HIIT and SIT were perceived as more adverse than MIE. This is why VIIE and HIIT were expected to elicit more negative affective responses than MIE in the present study. Another explanation of the reduced affective responses during higher intensity interval exercise is due to the intensity of the exercise being above the anaerobic threshold. Previous studies have found that exercise protocols that are above the anaerobic threshold are perceived more negatively than those

below the anaerobic threshold, such as MIE (Ekkekakis et al., 2011; Oliveira et al., 2018). Based on the previous literature, more research is necessary to determine why there was no significant difference in the change in affect from rest between trials in the present study.

Although HIIT and VIIE elicited similar affective responses over time, post-exercise enjoyment of VIIE was significantly higher than HIIT. There was no significant difference in enjoyment between MIIE compared to VIIE or HIIT. It was originally hypothesized that post-exercise enjoyment would be highest for VIIE, slightly lower for HIIT, and lowest for MIE. However, enjoyment was found to be lowest in HIIT. Previous studies by Bartlett et al. (2011) and Thum et al. (2017) concluded that enjoyment was higher during HIIT than MIE, even though affect was lower in HIIT. This response is thought to be due to subjects feeling a stronger sense of accomplishment and more invigorated after completing HIIT (Thum et al., 2017). In terms of the present study, subjects may have found the varied work rates of VIIE to be more invigorating and stimulating than the consistent work rates of HIIT and MIE. The lower enjoyment of HIIT may also be because the higher VO_2 elicited during exercise was not perceived as enjoyable as the cardiovascular stress induced by VIIE or MIE.

The findings of this study suggest that VIIE is a viable alternative to HIIT and MIE. VIIE elicited a HR response similar to that of HIIT and significantly higher than MIE, despite evoking a lower VO_2 than HIIT. Eliciting a lower VO_2 proved favorable for subject perception of the VIIE protocol. The physiological stress of HIIT resulted in lower enjoyment and low affective responses, particularly at 100% of exercise. On the other hand, enjoyment of VIIE was found to be significantly higher than HIIT and similar to MIE. The perceptual responses of affect and enjoyment are important indicators of exercise participation and adherence (Bartlett et al.,

2011; Stork et al., 2017). As VIIE offers physiological and perceptual advantages while also being time efficient, this protocol may be an appropriate alternative to HIIT or MIE.

A limitation of this study was the sample size of participants. Only having seven participants does not give the findings as much power as needed to adequately conclude the similarities and differences between the three protocols. It is possible that the low sample size is why the change in affect was not significantly different between trials and having more participants may strengthen the difference between MIE and the higher intensity protocols. Having a larger sample size may provide more significant differences, such as in the HR response between VIIE and HIIT as well as the change in affective responses from rest. Another limitation of this study was the demographics of the participants. All seven subjects were generally young and healthy adults. The physiological and perceptual responses may be different in older populations or differences may be established between men and women. These responses are important to understand in order to learn which exercise protocol will maximize the health benefits in each demographic, while also finding enjoyment in the activity being performed. Determining the physiological and perceptual responses will help maximize exercise participation and adherence.

Future studies may benefit from a larger sample size as well as exploring different demographics. Once more subjects participate in these trials, it would be interesting to explore the differences in physiological and perceptual responses between men and women as well. There may be differences in the perception of the three protocols between men and women based on the physiological responses elicited by the exercises, which could influence exercise adherence. It may also be beneficial to adjust the VIIE and/or HIIT protocols to attempt to elicit

more similar VO_2 responses, while keeping the same level of post-exercise enjoyment in VIIE, in order to maximize possible health benefits. This may be done by increasing the duration of the supramaximal or near-maximal bursts during VIIE, or by decreasing the duration of the bursts during HIIT.

Conclusion

The purpose of this study was to look at the physiological and perceptual responses during and after three work-matched exercise protocols. While HIIT elicited a significantly higher VO_2 compared to VIIE and MIE, VIIE provided a similar HR response. VIIE and HIIT were both significantly more physiologically demanding than MIE. Subjects' perceived exertion was also significantly higher in HIIT and VIIE than MIE. Along with the lower perceived exertion, affective responses decreased the least from rest during MIE. Although affective responses were low for both VIIE and HIIT, enjoyment was significantly higher after completion of VIIE than HIIT. The high physiological responses and more positive perception offer VIIE as an acceptable alternative to HIIT and MIE.

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