CHANGES IN ENERGY INTAKE AND APPETITE FOLLOWING DIFFERENT INTENSITIES OF AEROBIC EXERCISE

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Changes in Energy Intake and Appetite Following Different Intensities of Aerobic Exercise

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ABSTRACT

This research evaluated changes in appetite, energy intake, and body composition following 15 sessions of both moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT) in overweight and sedentary adults (n = 4 female, n = 2 male). All subjects performed both MICT and HIIT. Paired t-tests were used to analyze data between testing sessions. A repeated-measures ANOVA along with a Bonferroni adjustment was used for measures over the study duration. Chronic appetite was unchanged over the study duration, but appetite post-exercise was 5.7% higher in HIIT ($p = 0.03$) in the first session compared to MICT. Energy intake was reduced within subjects ($p = 0.023$) over the study. Systolic blood pressure was significantly reduced ($p = 0.027$) between post-testing 1 and post-testing 2. While this study suggests aerobic exercise has no effect on chronic feelings of appetite, more research is needed as energy intake was reduced.

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DEDICATION

This thesis is dedicated to my parents. Mom, you have taught me the importance of education and gave me the ability to pursue my passions in academics. You have always supported any decision I have made, and I could not ask for a better role model. Dad, you are an inspiration to me and have always encouraged me to chase my dreams. You have taught me how to deal with adversity and be stronger for it. Without the both of you, I never would have been able to complete such a project.

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LIST OF ABBREVIATIONS

MICT...moderate-intensity continuous training

HIIT..high-intensity interval training

ACSM ....American College of Sports Medicine

RPE ....ratings of perceived exertion

VO2 max..cardiovascular fitness

GLP-1..glucagon-like peptide 1

PYY...peptide YY

PP ....pancreatic polypeptide

CKK ....cholecystokinin

Par-Q ....physical activity readiness questionnaire

VAS...visual analog scale

VO2...volume of oxygen

CHAPTER I. INTRODUCTION

Obesity is major health concern worldwide as prevalence of obesity have risen each decade in the later 20th century in all but a few countries (Di Cesare et al., 2016). This increased rate has major negative health implications as four million deaths were associated with obesity related complications in the year 2015 (Afshin et al., 2017). These obesity related deaths should be expected, as obese individuals have an 18% higher mortality rate than their normal weight peers (Flegal, Kit, Orpana, & Graubard, 2013). Cardiovascular disease is the main risk for overweight and obese individuals, but the strain of obesity is not limited to this disease (Afshin et al., 2017). Cardiovascular disease is the leading cause of death in the United States, as it is estimated that 92.1 million adults have the disease. Fortunately, physical activity is a modifiable risk factor for cardiovascular disease that also can improve body composition.

Adults are recommended to participate in aerobic exercise on multiple days of the week, accumulating 150 minutes of moderate exercise over five days or 75 minutes of vigorous exercise over three days. Also, adults are recommended to participate in resistance training at least twice per week, stimulating all major muscle groups. (ACSM, 2013). However, exercise participation rates are very low in the United States. Only 43.5% of adults reported meeting aerobic exercise guidelines, 21.9% reported meeting resistance training guidelines, and 18.2% reported meeting both simultaneously (Carlson, Fulton, Schoenborn, & Loustalot, 2010). As with obesity, inactivity is also associated with higher mortality rates, and to a certain degree more physical activity leads to reduced risk of chronic disease (O'Donovan, Lee, Hamer, & Stamatakis, 2017). While the literature supports physical activity and exercise as a means of reducing chronic disease and improving body composition, recommendations from major health organizations are vague and leave many questions to be answered.

Both aerobic and resistance exercise promote improvements in body composition, physical fitness, and metabolic health. Aerobic exercise is more influential on fat mass, reducing fat mass more than resistance training in overweight individuals (Bales et al., 2012). Aerobic exercise is also associated with improvement in modifiable risk factors of cardiovascular disease by reducing blood pressure and increasing high-density lipoprotein (Carrick-Ranson et al., 2014; Hespanhol, Pillay, van Mechelen, & Verhagen, 2015).

Emerging research supports the concept that exercise impacts energy intake and portions of the endocrine system involved with eating behavior. Some exercise interventions have caused individuals to consume more calories than when inactive and to report a preference for high energy foods (Finlayson, Bryant, Blundell, & King, 2009). Results have also indicated that more exercise may not promote more weight loss, causing some to question current recommendations for exercise and weight loss (Rosenkilde et al., 2012). In contrast, other exercise interventions have found individuals to consume less energy after exercise, especially when exercise intensity is increased (Vatansever-Ozen, Tiryaki-Sonmez, Bugdayci, & Ozen, 2011). As with energy intake, experiments measuring changes in the hunger stimulating hormone ghrelin are inconsistent but are enough to support the notion that exercise impacts the connection between brain and stomach.

Exercise interventions investigating the effects of repeated aerobic exercise on body composition and eating behavior are very limited. Few studies have explored how two different intensities of aerobic exercise that expend similar amounts of energy may impact body composition and energy intake over subsequent weeks. Also, most studies to date are acute in nature, not allowing the subjects to experience significant body composition changes which can impact eating behavior (Lean & Malkova, 2016). The purpose of this study is to examine the effects of aerobic exercise programs utilizing different intensities and their effects on body composition, subjective hunger, and energy intake.

Statement of the Problem

Evidence based practice fails to identify the exercise interventions which best support weight loss. Few studies compare exercise interventions of different intensities while keeping the energy expenditure constant between the two. While research exists that compares how different intensities of aerobic exercise impact eating behavior, the literature lacks studies that compare the two when repeated over time.

Purpose of Study

The purpose of this study is to examine the effects of two different intensities of aerobic exercise on body composition, energy intake, and subjective feelings of hunger in sedentary and overweight adults over two five-week exercise periods.

Research Questions

Do different intensities of aerobic training impact body composition differently?

Do different intensities of aerobic training impact subjective feelings of hunger differently?

Do different intensities of aerobic training impact energy intake?

Are changes in appetite or energy intake related to exercised induced changes in body composition?

Limitations

Sex differences – subjects will be of both genders and may have different energy intake or subjective appetite responses to aerobic exercise.

Age difference – age may impact how participants respond to exercise.

Subjective appetite measurement – appetite will be measured using a visual analog scale which may be interpreted differently between individuals or misunderstood.

Short duration of exercise interventions – five weeks of aerobic exercise may not be enough to drive changes in body composition, energy intake, or appetite.

Subject compliance – individuals will be given many instructions to follow during the intervention and pre-testing which if not followed could impact results.

Sample size – relatively small number of subjects may be unable to detect significant changes in body composition, energy intake, or appetite after training.

Dropout – exercise interventions, especially of high intensity, traditionally have high dropout rates.

Previous exercise participation – previous exercise practices may alter body composition and dietary response to new exercise intervention.

Motivation – maximal exercise testing and regular aerobic exercise involves a certain amount of intrinsic motivation which some individuals may lack.

Inaccurate dietary records – subjects may mistakenly or purposely report their dietary intake inaccurately.

Definitions

Body Composition – the relative percentage of body mass that is fat or fat-free tissue (ACSM, 2013).

High-intensity Interval Training – alternating between short periods of intense exercise with recovery periods that are stationary or of mild intensity (Roy, 2013).

Moderate intensity continuous training – Exercise performed between 40-60% of maximal capacity (ACSM, 2013).

Rate of Perceived Exertion – A tool for estimating effort and exertion, breathlessness, and fatigue during physical work (Borg, 1998).

Enteric Nervous System – System of sensory neurons, motor neurons, and interneurons embedded in the wall of the gastrointestinal system (Watson, Kirkcaldie, & Paxinos, 2010).

Dietary Restriction – An intentional reduction of total energy intake without causing malnutrition (Katewa & Kapahi, 2010).

Body Mass Index – (BMI) A predictor of body fatness, calculated as a person's weight in kilograms divided by the square of height in meters (Prevention, 2016).

Overweight – A BMI score of 25 to 29.9 is considered overweight in adults (Prevention, 2016)

Obesity – A BMI score of 30 or higher is considered obesity in adults (Prevention, 2016).

CHAPTER II. LITERATURE REVIEW

Intensity of Aerobic Exercise

The U.S. Department of Health and Human Services and the American College of Sports Medicine both recommend that adults accumulate either 150 minutes of moderate-intensity aerobic exercise, 75 minutes of high-intensity exercise, or a combination of the two each week (ACSM, 2013). Moderate intensity continuous training (MICT) as defined by the ACSM, is performed between the ranges of 40% and 60% of maximal aerobic capacity. Recommendations also state that more time, up to 300 minutes support greater gains in fitness and larger amounts of weight loss (ACSM, 2013). Participation and adherence to aerobic exercise is also associated with moderate weight loss, between 2-6%. (Garber et al., 2011). Moderate-intensity continuous training (MICT), is prescribed in the literature often at intensities up to 70% (De Feo, 2013; Higgins, Fedewa, Hathaway, Schmidt, & Evans, 2016).

High-intensity interval training (HIIT) has become popular in recent years, being advertised as a time saving way to improve aerobic fitness and body composition in comparison to traditional MICT (De Feo, 2013). This intensity focused mode of aerobic exercise has been adapted from the protocols utilized by track athletes for decades (Myers, 2002). According to the ACSM, HIIT consists of alternating short periods of intense exercise with recovery periods of rest or low intensity exercise. A typical intense period will last between 15 seconds to four minutes at an intensity between 80 and 95% maximal heart rate. Recovery periods often last longer or an equal amount of time as the intense period. During this time participants either rest or do submaximal exercise between 40 and 50% of maximal heart rate (Roy, 2013).

MICT has long been prescribed to individuals enrolling in weight loss programs to reduce or maintain weight loss. The ACSM suggests that moderate-intensity physical activity for 150 to 250 minutes a week is enough to prevent weight gains of 3% or more, and that it may result in modest weight loss without dietary restriction (Donnelly et al, 2009). This relationship of continuous aerobic exercise and moderate weight loss was evident in an 18-month trial where sedentary, overweight adults participated in 30 minutes of MICT three times per week. Subjects lost 2.1% of their bodyweight over the duration of study without dietary restriction (Donnelly, Jacobsen, Heelan, Seip, & Smith, 2000). Similar results were also experienced by 38 overweight adults who participated in an eight-month intervention, performing moderate intensity aerobic exercise three times per week for an average of 130 minutes per week. Subjects reduced body weight (-1.76 kg, $p = 0.001$) over the duration of the intervention which equated to a significant reduction in body fat percentage (-1.01, $p = 0.003$) (Willis et al., 2012). While this reduction in weight and body fat percentage were found to be statistically significant, these improvements are not of clinical significance.

Similar results were found by Wewege et al. (2017) in a meta-analysis comparing short term interventions (10.4 ± 3.1 weeks) of HIIT and MICT. Subjects ($n = 208$) in the MICT protocols lost 2.1 kg of fat mass during their respective interventions (Wewege, van den Berg, Ward, & Keech, 2017). While MICT results in modest reductions in body weight and fat mass in both short and long-term interventions, these results may not be the desired clinically significant results. Since exercise alone is not enough to reduce bodyweight in overweight adults more than a few percent, dietary restriction and exercise have been combined or compared. To evaluate this comparison, 51 subjects participated in a 16-week randomized control trial that had individuals split into one of four groups. Subjects were split into groups where they either maintained their current habitual eating or were given a tailored program reducing their daily energy intake by 1000-1500 calories. These two groups were further split into light exercise control group and a vigorous continuous exercise group. The group who ate at a maintained diet lost 1.55 kg with vigorous exercise, and the group who restricted their diet and exercised lost 11.66 kg over the duration of the intervention (Cox, Burke, Morton, Beilin, & Puddey, 2004) Thus dietary restriction and vigorous exercise may have strong additive effects on weight loss.

In another comparison of dietary restriction and exercise for weight loss, subjects either restricted energy intake enough to reduce body fat mass by one third, participated in MICT designed to reduce body fat mass by one third, or were in a control group that did nothing. After the year-long protocol, dieters reduced their weight by 7.8 kg ($p < 0.001$), and the exercise group reduced weight by 4.6 kg ($p < 0.001$). The control group had no significant changes in body composition (Wood et al., 1988). In a similar study subjects ($n = 51$) participated in a control, dietary restriction, or MICT intervention designed to reduce bodyweight by 0.6 kg per week. Both the MICT (-7.6 kg, $p < 0.05$) and dietary restriction (-7.4 kg, $p < 0.05$) groups reduced weight significantly and in a similar amount (Thong, Hudson, Ross, Janssen, & Graham, 2000). When dietary restriction and four different yearlong self-guided treadmill exercise interventions were combined, all groups lost similar amounts of weight ($p < 0.001$). The group who partook in the high-volume program designed to be more intense lost the most amount of weight (Jakicic, Marcus, Gallagher, Napolitano, & Lang, 2003). While MICT may not promote the amount of weight loss that dietary restriction or a combined approach can, different exercise interventions can influence weight loss with or without dietary restriction.

Participation in HIIT has been shown to save time and provide positive adaptations similar to that of MICT. In the previously reported meta-analysis by Wewege et al. (2017) it was concluded that HIIT had a small effect on body fat mass (SMD = -0.44, $p = 0.005$) and MICT had a medium effect (SMD= -0.5, $p = 0.0005$). Nevertheless, they were not significantly different from one another. Subjects in both groups also experienced improvements in waist circumference (HIIT, $p = 0.03$; MICT, $p = 0.006$). While the results on body composition are not different, subjects in the HIIT group exercised an average of 63 minutes less per week than their MICT counterparts (Wewege et al., 2017). Thus, HIIT can be as effective as MICT for improving body composition with 40% less time commitment.

The design and implementation of HIIT protocols largely factor into the success experienced by participants. Nevertheless, participants in some HIIT protocols do not experience similar positive adaptations as do their MICT counterparts (Keating et al., 2014). In a 12-week randomized control trial of 38 subjects comparing HIIT and MICT cycling, individuals in the MICT training group had a medium reduction in weight of 0.8 kg, while HIIT participants saw a small gain in weight of 0.2 kg. Participants in the HIIT group did not reduce body fat percentage, while individuals participating in MICT reduced body fat percentage ($2.6 \pm 1.1\%$, $p < 0.05$) (Keating et al., 2014). Overweight untrained men participating in a running intervention comparing control, HIIT, and MICT experienced similar results. Subjects in the HIIT group did not significantly improve body composition while MICT participants did reduce body fat percentage (24.3 ± 1.6 to 22.6 ± 1.7, $p < 0.05$) over the 12 weeks of training (Nybo et al., 2010). Practical takeaways from these two studies would lead one to believe that MICT is superior to HIIT for improving body composition.

As with any exercise program, some individuals respond more favorably than others. Obese adult women participated in a 12-week cycling intervention comparing HIIT, MICT, and a second HIIT protocol which expended half the energy of the other two interventions. Participants all improved similarly in both body composition and aerobic fitness. No between group differences were found, indicating the HIIT group who expended half the energy exercising may be just as effective for improving body composition (Martins et al., 2016). In a similar study comparing HIIT and MICT in obese young adult women of six weeks, researchers again found HIIT to be superior to MICT for improvements in body composition. Independent of substantial changes in bodyweight, individuals participating in HIIT had better reductions in total fat mass (3.6% ± 5.6% vs. 0.6% ± 3.9%, $p = 0.007$) (Higgins et al., 2016). In these women, HIIT would be superior for improving body composition relative to MICT. Exercise mode, frequency, and volume must be compared to quantify the difference between the two intensities of exercise.

Using HIIT to improve body composition in the absence of weight reduction has been researched numerous times. Forty-three overweight women participating in a 12-week training intervention comparing HIIT and MICT on body composition found both interventions to have similar positive effects upon body composition. Women participating in MICT improved body fat percentage by 2.8% ($p < 0.05$), and decreased bodyweight by 1.7 kg ($p < 0.05$). Participants in the HIIT group decreased body fat by 3.1% ($p < 0.05$), and decreased bodyweight by 1.9 kg ($p < 0.05$). Women in the HIIT group decreased abdominal visceral fat 11.8 cm^2, and abdominal subcutaneous fat area by 49.7 cm^2 ($p < 0.05$), significantly more than the MICT group (Zhang et al., 2015). Maillard et al. (2016) compared HIIT to MICT, noting better improvements in abdominal fat mass in 17 obese postmenopausal women with type 2 diabetes over 16 weeks. The women in the HIIT group decreased total abdominal fat mass by 8.3% ($p \leq 0.05$) and visceral fat mass by 24.2% ($p \leq 0.05$) while the women in the MICT group did not experience significant improvements in either measurement (Maillard et al., 2016). Thus, HIIT training in female obese individuals can decrease abdominal fat storage and potentially more so than MICT.

Cycling and running are the modes of aerobic exercise most often utilized in training studies comparing changes in body composition and physical fitness. Running is more advantageous from a time standpoint, as more energy is expended in comparison to cycling. In a crossover study comparing caloric expenditure and time between cycling and running, participants expended 400 calories 261 seconds quicker during running ($p < 0.001$). Oxygen uptake and heart rate were also higher during the running intervention ($p < 0.001$) (Cunha, Midgley, McNaughton, & Farinatti, 2016). Running engages more muscle mass leading to a higher energy cost (Bergh, Kanstrup, & Ekblom, 1976; Kravitz, Robergs, Heyward, Wagner, & Powers, 1997). These researchers concluded that running would be superior for weight loss from a metabolic standpoint. In a confirmation study, Wewege et al., (2017) found that among overweight and untrained individuals, treadmill runners experienced weight loss, equating to a 10% reduction in body fat, while cycling had no measurable effect (Wewege et al., 2017). They concluded running was more effective than cycling for weight loss in overweight and sedentary individuals. More research is needed into the practicality of running in this population as it is associated with a high incidence of musculoskeletal injuries (van Gent et al., 2007).

Volume and intensity of aerobic exercise are two factors that have not been well standardized between studies. This inconsistency makes it difficult to pinpoint the ideal protocol of aerobic exercise, especially in HIIT. Researchers comparing two volumes of HIIT to MICT found significant reductions in body weight among all groups. Subjects in the low volume HIIT protocol, designed to expend half the energy of the first two interventions, lost the most weight of any group (Martins et al., 2016). This research may indicate that even a small amount of aerobic exercise can be beneficial in overweight adults. This finding was replicated by research comparing four different treadmill running protocols over one year. Subjects ($n = 184$)

completed protocols designed to expend either 1000 or 2500 calories per week. Subjects were further split by intensity utilizing RPE into moderate or vigorous intensity. All groups lost significant amount of body weight, but no group was significantly different from one another (Jakicic et al., 2003). This indicates volume may not have strong implications on weight loss when energy expenditure is controlled. More research is needed to standardize volumes of aerobic exercise for different intensities.

Concerns about the safety of HIIT are warranted, but evidence supports this form of high intensity exercise as a safe mode of exercise for the overweight and inactive individual. A meta-analysis compiling the effects of HIIT on patients with coronary artery disease included seven studies ranging from 10 to 52 weeks in length (Cornish, Broadbent, & Cheema, 2011). No life threatening or adverse cardiovascular events occurred in the combined 213 subjects during the exercise intervention, which indicates the benefits may outweigh any associated risks with HIIT (Cornish et al., 2011). The seemingly limited danger found with HIIT is important as the individuals included in the review are considered a high-risk population being both overweight and having coronary artery disease. More research into this topic is needed, but if the overweight individuals with coronary artery disease were safe during HIIT, individuals who are overweight without any other negative health implications might be as well.

The intensity of HIIT for the overweight and sedentary individual could be a barrier to entry, but evidence supports adjusted intervals can support adherence and enjoyment of exercise while promoting positive adaptations comparable or superior to MICT (Martinez, Kilpatrick, Salomon, Jung, & Little, 2015). Overweight adults participating in 10 weeks of aerobic cycling classes with either a HIIT or MICT design all had similar and significant improvements in VO_{2max} and fat mass ($p < 0.001$). While physical results were similar, the HIIT group had 22%

higher adherence than the MICT group ($p < 0.001$) (Shepherd et al., 2015). Overweight individuals participated in a study comparing intense continuous aerobic exercise and three different HIIT protocols using 30, 60, and 120 seconds. Enjoyment of exercise declined in the 120 second intervals and intense continuous exercise (Martinez et al., 2015). The increased enjoyment experienced during HIIT in comparison to MICT has been repeated, and has led to better adherence rates over time (Heinrich, Patel, O'Neal, & Heinrich, 2014; Kilpatrick et al., 2015). Thus, HIIT may offer a safe alternative to MICT for overweight individuals to improve body composition and physical fitness while saving time and increasing adherence.

Appetite and Exercise

Exercise and physical activity are often prescribed to overweight and obese individuals in combination with dietary restriction to create a negative energy balance and support weight loss. Individuals are often frustrated with results that are less than one would expect with the amount of energy expended through exercise. Evidence suggests that compensation in eating behavior response to exercise will affect exercise-induced changes in body composition (King et al., 2007). Subjective measurements of eating behavior include visual analog scales of perceived hunger and food preferences, while objective measurements include reported energy intake and blood levels of various hormones involved in the gut-brain axis, which drives eating behavior.

Evidence is mounting in support of how the brain-gut connection can influence energy intake by either inhibiting or stimulating appetite. This system includes a complex relationship between the gastrointestinal tract, central nervous system, enteric nervous system, and adipose tissue that responds to mechanical, chemical, and pain sensations (Konturek, Konturek, Pawlik, & Brzozowki, 2004). This system can impact both acute and chronic eating behavior and is altered by both changes in physical activity and body composition. In the overweight and sedentary individual starting an exercise regime in hopes of losing weight, the gut-brain axis may have a more pronounced effect. Numerous hormones are secreted in the gastrointestinal tract in response to exercise and food intake, and in adipose tissue that are appetite suppressing, termed anorexigenic hormones. Only one hormone, ghrelin, is a known appetite stimulant, also referred to as orexigenic (Lean & Malkova, 2016).

Glucagon-like peptide 1 (GLP-1), peptide YY (PYY), pancreatic polypeptide (PP) and cholecystokinin (CKK) are all anorexigenic hormones secreted from various locations in the GI tract (Yu & Kim, 2012). GLP-1 is secreted in response to carbohydrate and fat consumption and inhibits appetite by stimulating insulin secretion, inhibiting glucagon, and slowing gastric emptying (Cabou & Burcelin, 2011; Willms et al., 1996). PYY is secreted along with GLP-1 and has the same function of inhibiting gastric emptying, responding mainly to fat intake (Pironi et al., 1993). CKK is produced in response to fat and protein intakes and inhibits appetite by slowing gastric emptying (Delzenne et al., 2010). PP also responds to food intake by slowing gastric emptying and pancreas function (Cummings & Overduin, 2007). Leptin is produced primarily in fat tissue. As body fat stores increase, more leptin is secreted. Leptin secretion signals the hypothalamus to suppress appetite and increase energy expenditure. Overweight individuals do not reap the appetite suppressing effects of leptin, as they build up a resistance to it (Morris & Rui, 2009). In contrast to leptin and the gut secreted anorexigenic hormones, ghrelin increases appetite. Ghrelin has its effects both in the stomach, and in the hypothalamus (Neary, Druce, Small, & Bloom, 2006). Ghrelin opposes the actions of the previous appetite suppressing hormones by increasing appetite and the speed at which the GI tract empties (Tack et al., 2006; Wren et al., 2001).

Leptin and ghrelin have an intertwined relationship, controlling eating behavior in the short term and altering behavior in relation to body composition changes. While it may not be secreted in the digestive tract, leptin can be altered through exercise-induced weight loss. A weight loss of 3.5 kg in overweight individuals participating in 12 weeks of aerobic exercise led to reductions in leptin levels both fasted and after a meal (Martins, Kulseng, Rehfeld, King, & Blundell, 2013). In response to acute exercise leptin levels do not change significantly (Vatansever-Ozen et al., 2011). This finding is not surprising, as acute exercise does not expend enough energy to cause meaningful reductions in adipose tissue. Thus, leptin likely is not directly affected by exercise, but by reductions in adipose tissue (Lean & Malkova, 2016). Ghrelin, and more importantly acylated ghrelin is impacted by both acute exercise bouts and long-term exercise adherence. Twelve overweight adults participated in a crossover study comparing an acute bout of HIIT cycling, MICT cycling, and low volume HIIT intervention. Ghrelin was significantly decreased with participation in both the HIIT and MICT cycling groups ($p < 0.05$) compared to control (Martins et al., 2015). Higher intensities of aerobic exercise seem superior as four thirty second sprints on a cycle were enough to elicit substantial reductions in acylated ghrelin ($p = 0.03$) in overweight adults, while 60 minutes of brisk treadmill walking did not reduce acylated ghrelin, albeit in normal weight individuals (Holliday & Blannin, 2017; King, Wasse, Broom, & Stensel, 2010).

Higher intensity exercise, specifically HIIT, has become a popular recommendation for weight loss. This may be in response to recent literature reporting positive outcomes on body composition while saving time in comparison to MICT (Wewege et al., 2017). Higher intensities of exercise have been theorized to inhibit appetite due to increased lactate production and reduced blood flow to the digestive system (Hazell, Islam, Townsend, Schmale, & Copeland, 2016). Lactate binds to ghrelin producing cells and inhibits ghrelin production (Engelstoft et al., 2013). The relationship between exercise intensity, lactate, and energy intake has not been performed on overweight individuals. In a counterbalanced comparison of MICT, HIIT, and high intensity continuous treadmill running in healthy males, subjective appetite was reduced in all three groups ($p < 0.004$). The appetite was reduced more in the HIIT ($p < 0.001$) and high intensity continuous trial ($p < 0.026$) compared to the MICT. This greater reduction in appetite was matched with greater reductions in ghrelin and higher lactate values (Islam et al., 2017). Thus, increased exercise intensity may decrease appetite. This research should be validated in overweight and obese populations.

High intensities of exercise have been shown to support reductions in energy intake in sedentary overweight individuals. Overweight men participated in four different trials that included a control, HIIT, sprint interval, and MICT intervention. Post exercise energy intake was reduced in both HIIT ($p = 0.038$) and sprint interval trials ($p = 0.004$). Energy intake also remained reduced in the 38 hours after exercise in the sprint interval trial ($p < 0.05$) in comparison to control and MICT. The energy intake reduction was met with reduced ghrelin ($p < 0.05$) and higher lactate ($p < 0.014$) values in the sprint interval group compared to other trials (Sim, Wallman, Fairchild, & Guelfi, 2014). These findings support the concept that HIIT improves both subjective and objective measures of appetite in overweight adults. Higher intensities of exercise have been repeatedly reported to reduce appetite, ghrelin, and energy intake more than MICT (Beaulieu, Olver, Abbott, & Lemon, 2014; Broom et al., 2017; Holliday & Blannin, 2017).

The relationship between exercise and appetite can be complex and it may predict the success of exercise-induced weight loss. Acute and chronic participation in aerobic exercise can impact physiological and psychological systems involved in appetite regulation. Individuals who participate in high intensity exercise often respond more favorably. Long-term exercise interventions with multiple modes of exercise are needed as much of the literature has utilized short-term counterbalanced exercise bouts to draw conclusions. These studies are unable to explore the relationship between body composition changes, changes in physical fitness, and eating behavior. Body composition changes and long-term improvements in physical fitness may play just as large of role in energy intake as the exercise modality.

Conclusion

Overweight and obesity is a health crisis that is highly concerning as rates of obesity are rising in almost every country worldwide (Di Cesare et al., 2016; Finucane et al., 2011). Self-reported exercise participation rates are relatively low, as only 43.5% of adults in United States reported meeting aerobic exercise guidelines (Carlson et al., 2010). Exercise participation, especially aerobic exercise, may be performed to try and combat this issue and reduce body fat. Individuals often lose modest amounts of weight when participating in MICT for 8-18 months reducing total bodyweight by 1.7-2.1% without dietary restriction (Bateman et al., 2011; Donnelly et al., 2000). More success is seen when combining dietary restriction and MICT, but often not much more than dietary restriction alone. This phenomenon may be due to compensatory mechanisms, the gut-brain connection, and higher muscle mass losses when restricting calories in the absence of exercise.

Higher intensities of exercise and protocols like HIIT seem to have greater positive effects on appetite and allow individuals to save time in comparison to traditional MICT protocols. More research is needed to pinpoint which exercise protocols have the most beneficial results for weight loss. Much of the literature has performed acute exercise interventions to try and quantify the weight loss and appetite response to exercise, which misses how changes in body composition and physical fitness may impact eating behavior. Some of these protocols are unrealistic, having overweight and deconditioned adults perform intense intervals without building a base of aerobic fitness first. Studies involving aerobic exercise programs that are not only progressed through volume and intensity, but also graduating from MICT to HIIT may provide beneficial effects on weight loss and appetite not yet seen in the literature.

CHAPTER III. METHODS

Purpose

The purpose of this study was to examine the effects of two different intensities of aerobic exercise on body composition, energy intake, and subjective feelings of hunger in sedentary and overweight adults. Participants consisted of men and women aged 18-40 who are overweight (BMI $\geq$ 25). Participants were sedentary, defined as not having participated in more than one recreational exercise activity per week over the last six months. Individuals were recruited to participate in two interventions beginning with a moderate-intensity intervention for five weeks and finishing with another five weeks of a high-intensity interval training. A one-week washout period occurred between the trainings, to give subjects a break and allow acute effects of the first intervention to subside. The independent variable was the aerobic exercise intensity. Dependent variables included weight, VAS appetite scores, and reported energy intake.

Information Session

An informational session was held to explain the goals of the study and to answer any questions prospective subjects may have. During the informational session, potential participants were informed of both the risks and rewards of the intervention both verbally and in writing. Informed consent and a Physical Activity Questionnaire (PAR-Q) was completed prior to participation, see Appendix A. If interested participants answered “yes” on one or more questions of the PAR-Q, they were required to get physician approval to participate. Participants were excluded if they had any physical or psychological deterrent to strenuous aerobic exercise. This included any acute cardiac event, hypertension, angina, heart failure, pulmonary infarction, and pulmonary embolism. All medications were recorded, and individuals were excluded if they were taking β-blockers, nitrates, or antidepressants as these could impact our results or put the subjects in danger.

Anthropometric Measurements

One individual assessed several anthropometric measurements. Height was measured using a free-standing stadiometer (Seca GmbH & Co. Kg., Hamburg, Germany) and weight with the use of a calibrated electric scale (Detecto© DR600). Waist-to-hip ratio was calculated using hip and waist measurements measured by one trained researcher (Welborn & Dhaliwal, 2007). Waist was measured horizontally at the thinnest portion between umbilicus and xiphoid process. Hip was measured horizontally at the maximal circumference of the gluteal muscles (ACSM, 2013). Body composition was also tested with leg to leg bioelectrical impedance (Tanita TBF-300A, Arlington Heights, Illinois). Bioelectrical impedance has been shown to be reliable, and correlate well with dual X-ray absorptiometry ($P^2 = 0.92$) (von Hurst et al., 2016). To improve validity of bioelectrical impedance, subjects were encouraged to get a good night sleep beforehand, be well hydrated, avoid strenuous activity the day of the tests, and avoid caffeine consumption that day.

Energy Intake and Appetite

Energy intake throughout the duration of the study was estimated using a three-day food record listed under Appendix B. Subjects were instructed to record dietary intake on three days during weeks one and five of both interventions. Subjects recorded their food intake on Sunday, Monday, and Tuesday. These days included a weekday without exercise, a weekday with exercise, and one weekend day. The total caloric intake was averaged for the three-recorded days to provide pre- and post-intervention comparisons. Subjective feelings of appetite and hunger were tested using a visual analog scale which can be found in Appendix C. Visual analog scales have proven to be a reliable indicator of subjective feelings of appetite (Flint, Raben, Blundell, & Astrup, 2000). Four questions about hunger ("How hungry do you feel?"), satisfaction ("How satisfied do you feel?"), fullness ("How full do you feel?"), and prospective food consumption ("How much do you think you can eat?") were asked. Each question was associated with a 100-mm visual analog scale, which had opposing statements. The average of the four scores, with the satisfaction and fullness score inverted, was used as an overall appetite score (Flint et al., 2000; Islam et al., 2017).

Pretesting

Individuals were asked to avoid strenuous physical activity in the 48 hours leading up to their initial testing. Before attending testing, subjects were instructed to wear comfortable and loose-fitting athletic clothing. Subjects were also asked to refrain from alcohol, tobacco, and e-cigarrete consumption the 24 hours prior to testing. For the day of testing, subjects were asked to avoid food consumption for three hours leading into the test, and to avoid caffeine consumption entirely. For results consistent with their physical fitness, subjects were encouraged to get a good night's sleep beforehand and be well hydrated.

After lying supine for five minutes, systolic and diastolic blood pressure was measured manually using a sphygmomanometer. Subjects then completed their VO_2max test on the cycle ergometer (Monark, Vansbro Sweden) utilizing a MedGraphics ULTIMA Series metabolic cart (MGC Diagnostics, St. Paul, MN) to determine oxygen consumption. Heart rate was recorded using a POLAR (Kempele, Finland) heart rate monitor. The test began with a warm-up at a resistance of 50 W for 5 minutes. After the warm-up, resistance was increased by 25 W every two minutes until volitional fatigue. Participants were asked to cycle at a cadence between 60 and 70 rpm. Criteria for achieving VO_2max was set at a respiratory exchange ratio of 1.05

(Martins et al., 2015). The heart rate-VO_2 relationship was calculated based upon maximal heart rate which will be achieved by adding 5 beats to the highest value obtained during the test (Martins et al., 2015). This was used to estimate VO_2 and caloric expenditure during exercise. The estimated energy expenditure was calculated with an equation from McNeil and colleagues for continuous exercise (Schubert, Palumbo, Seay, Spain, & Clarke, 2017).

$$\text{Energy expenditure} = VO_2\ (\text{L} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) \times \text{Body weight (kg)} \times \text{Exercise duration } (\text{min} \cdot \text{wk}^{-1}) \times 5\ (\text{kcal} \cdot \text{L}^{-1}\ O_2)$$

Training

Following pretesting, participants began with five weeks of MICT three time per week. Subjects were administered their first VAS for measuring a baseline level of appetite prior to exercise. Sessions began at 60% of maximal heart rate and was increased up to 70% as their physical fitness increases. This intervention was designed specifically for each subject to expend 300 calories per session and was monitored by heart rate accordingly. Depending on the aerobic fitness of the subjects, sessions lasted between 30 and 55 minutes. This energy expenditure has been chosen as 250 calories has been shown to be ineffective at reducing hunger in overweight, sedentary individuals acutely and over a 12-week training cycle (Martins et al., 2017, 2015). Once completed, subjects had their baseline appetite post exercise measured using VAS. Subjects trained three days per week, measuring VAS before and after each training session.

After completing the first five-week session, subjects had a washout week where anthropometric assessments were remeasured. Subjects then completed 15 sessions of HIIT designed to match energy expenditure from the MICT trial. This intervention took seven weeks as university holidays and weather became schedule barriers. Exercise consisted of 60 seconds at a heart rate equivalent to 85-90% VO_2 peak followed by 240 seconds at heart rate equivalent to 50% VO_2. Depending on the individual's fitness they completed between 5-10 repetitions for a total of 30-50 minutes per session to hit their 300-calorie threshold. This intervention has worked well in overweight and inactive men and resulted in reduced energy intake when performed acutely (Sim et al., 2014). Work rates were adjusted over the duration of the intervention as individual's fitness increased.

Dietary intake throughout the training was assessed during weeks 1 and 5 of both interventions. Subjective feelings of appetite were recorded before, directly after, and one hour after completing exercise. Subjects were instructed to avoid alcohol consumption in the 24 hours prior to exercise sessions, and to avoid eating or consuming caffeine in the hours leading into exercise.

Post-Testing

In the week following completion of the intervention, individuals returned to the facility one more time for post-testing. Individuals had their height, weight, waist-to-hip ratio, body composition and resting heart rate measured.

Analysis

Statistical analysis was performed with SPSS 25.0 (SPSS Inc., Chicago, IL). Statistical significance was set at $p < 0.05$. Repeated-measures ANOVA was used to calculate changes in subjective appetite and changes in body composition, weight, and energy intake over the duration of the study. Pairwise comparisons with Bonferroni corrected p-values to control for type 1 family-wise error rate were utilized to compare means between testing sessions.

CHAPTER IV. CHANGES IN ENERGY INTAKE AND APPETITE FOLLOWING DIFFERENT INTENSITIES OF AEROBIC EXERCISE

Abstract

Obesity is a major health concern worldwide and aerobic exercise is supported to combat obesity and other related comorbidities. However, it is not well understood how energy intake is affected by different exercise intensities. **Purpose:** To determine the effects of two different intensities of repeated stationary cycling on subjective feelings of hunger, energy intake, and body composition in sedentary, overweight adults. **Methods:** Six sedentary adults (22.0 ± 3.6 years, BMI: 28.8 ± 3.6kg/m^2) were included. Baseline assessments of VO_{2max}, anthropometry, and body composition were taken. Following, subjects began a five-week period of training with three weekly lab visits. Training sessions were designed to burn 300 kcal and based upon VO_{2max}. During the first period subjects cycled at heart rate equivalent to 60-70% of their maximal aerobic capacity. After a rest week and testing session, subjects performed 15 sessions of High-Intensity Interval Training (HIIT) over a seven-week period. Intensity alternated between heart rates of 85-90% for 60s and 50% for 240s of their maximal aerobic capacity. A visual analog scale (VAS) assessed subjective feelings of hunger before, directly post, and one-hour post exercise at each session. Three-day food records were recorded in the first and fifth week of each period. Paired t-tests were used to analyze data between testing sessions. A repeated-measures ANOVA along with a Bonferroni adjustment was used for measures over the study duration. **Results:** Chronic appetite was unchanged over the study duration. However, appetite post-exercise was 5.7% higher in HIIT (p = 0.03) when comparing the first exercise session. Energy intake was reduced within subjects (p = 0.023) over the study duration. No improvements in BMI, body fat percentage, weight, waist-to-hip ratio, or resting heart rate were found at any point in the study. Systolic blood pressure was significantly reduced (*p* = 0.027) between post-testing 1 and post-testing 2. **Conclusion:** This study suggests that cycling regardless of intensity had no chronic effect on subjective appetite or body composition in overweight and sedentary adults. However, results indicated that energy intake was reduced within our subjects which would be unexpected with no changes in chronic appetite or body composition. Due to the high variability of these types of data, more research is needed to pinpoint which aerobic exercise protocols best support weight loss. However, it seems that aerobic exercise, especially HIIT, can positively influence biomarkers of health even in the absence of weight loss or composition improvement.

Introduction

Obesity is major health concern worldwide as obesity rates have risen each decade in all but a few countries (Di Cesare et al., 2016). This increased rate has had major health implications, as four million deaths were associated with obesity and its related complications in the year 2015 (Afshin et al., 2017). Many individuals turn to physical activity for weight loss, as it is the most common reported motivation for being physically active. Lack of time is reported as the biggest barrier to being physically active by adults (Hoare, Stavreski, Jennings, & Kingwell, 2017). Participation in exercise programs is relatively low in the United States, with only 54% of adults meeting guidelines for aerobic exercise (Center for Health Statistics, 2017).

Moderate-intensity continuous training (MICT), generally performed between 40%-to-70% of aerobic capacity, has long been prescribed to individuals enrolling in weight loss programs to reduce or maintain weight loss. The American College of Sports Medicine suggests moderate-intensity physical activity for 150-to-250 minutes a week is sufficient to prevent weight gains of 3% or more, and that it may result in modest weight loss without dietary restriction (Donnelly et al., 2009). Unfortunately, participation in aerobic exercise may cause individuals to feel hungrier and consume more energy than when sedentary (Finlayson et al., 2009). Also, higher volumes of exercise may not lead to higher amounts of weight loss which is motive to question current physical activity guidelines (Rosenkilde et al., 2012). Combined with disappointing weight loss, these negative dietary compensations may be another reason for low exercise participation rates.

Fortunately, some exercise interventions in healthy subjects have supported improved eating behavior by reducing energy intake after exercise, with more favorable results often coming from high-intensities (Vatansever-Ozen et al., 2011). A meta-analysis compared the effects of MICT and high-intensity interval training (HIIT), a form of aerobic exercise alternating short periods of intense work with short periods of rest or low intensity exercise, in overweight adults. Body composition results were similar between the two, but HIIT required 40% less time exercising (Wewege et al., 2017). The combination of reduced time commitment and positive influence on eating behavior may make HIIT appropriate for overweight and sedentary individuals. Therefore, this study aimed to compare the effects of MICT and HIIT performed serially on subjective appetite, energy intake, and body composition.

Subjects and Methods

Six overweight and sedentary individuals (n = 4 female, n = 2 male), with a mean age of 22.0 ± 3.6 years and mean body mass index (BMI) of 28.8 ± 3.6 kg/m^2 completed the study. Sedentary was defined as having participated in one or less recreational physical activity sessions per week over the previous six months. Exclusion criteria were history of acute cardiac events, hypertension, angina, heart failure, pulmonary infarction, and pulmonary embolism. During an information session, participants filled out a PAR-Q+ to screen for exclusion criteria.

Medications were recorded and individuals taking β-blockers, nitrates, or antidepressants were excluded. Participants were also excluded if they had a BMI ≥ 35kg/m^2, as values over this mark can decrease reliability of bioelectrical impedance. Participants were allowed to miss two sessions while maintaining inclusion.

Participants completed two exercise periods which included 15 intervention sessions for each condition with a non-randomized repeated measures design. Participants performed supervised MICT sessions during the first five-week period, had a washout week of rest, and then completed supervised HIIT during the second seven-week period. Due to multiple university closings caused by holidays and weather cancellations the HIIT period took longer to perform the prescribed 15 sessions.

Several measurements were recorded before and after each exercise period. The pre-testing session began with a single researcher manually gathering heart rate and blood pressure after participants rested for five minutes. While wearing light athletic clothing, participants had their height measured with a free-standing stadiometer (Seca GmbH & Co. Kg., Hamburg, Germany) and weight with a calibrated electric scale (Detecto© DR600). Waist-to-hip ratio was calculated using hip and waist measurements taken by one trained researcher. Waist was measured horizontally at the thinnest portion between umbilicus and xiphoid process. Hip was measured horizontally at the maximal circumference of the gluteal muscles. Body composition was then assessed with a leg – to – leg bioelectrical impedance machine (Tanita TBF-300A, Arlington Heights, IL). Pre-testing concluded with a VO_{2max} test performed on a cycle ergometer (Monark, Vansbro Sweden) utilizing a MedGraphics ULTIMA Series metabolic cart (MGC Diagnostics, St. Paul, MN) to determine oxygen consumption. Heart rate was recorded using a POLAR (Kempele, Finland) heart rate monitor. The test began with a warm-up at a resistance of

50 W for 5 minutes. After the warm-up, participants maintained a cadence of 50 rpm with resistance being increased by 25 W every two minutes until volitional fatigue Testing was repeated on the final day of training in both MICT and HIIT, excluding the VO_{2max} test.

The intervention was designed to have participants exercise three times per week during both MICT and HIIT. Two participants missed one session of exercise. Exercise was performed on a cycle ergometer (Monark, Vansbro Sweden) with participants wearing a POLAR (Kempele, Finland) heart rate monitor to control exercise intensity. Both MICT and HIIT were individually planned to expend 300 kcal based upon the heart rate-VO_2 relationship acquired during their VO_{2max} tests utilizing an equation from McNeil and colleagues (McNeil, Brenner, Courneya, & Friedenreich, 2017).

$$\text{Energy expenditure} = VO_2\ (L \cdot kg^{-1} \cdot min^{-1}) \times \text{Body weight (kg)} \times \text{Exercise duration } (min \cdot wk^{-1}) \times 5\ (kcal \cdot L^{-1}\ O_2)$$

During the MICT protocol, participants cycled at an intensity of 60-70% VO_{2max} while maintaining a cadence between 50-70 rpm. Work rate was adjusted to keep heart rate steady. Depending on the individual, exercise lasted anywhere between 29-56 minutes. During the HIIT intervention participants cycled at 85-90% VO_{2peak} for 60 s followed by 240 s recovery period at 50% $VO2_{peak}$. Depending on the individual level of fitness, 5-10 repetitions were completed for a total of 30-55 minutes.

Subjective feelings of appetite and hunger were assessed using a visual analog scale (VAS). Visual analog scales have shown to be a reliable indicator of subjective feelings of appetite (Flint et al., 2000). Four questions about hunger (“How hungry do you feel?”), satisfaction ("How satisfied do you feel?"), fullness ("How full do you feel?"), and prospective food consumption ("How much do you think you can eat?") were asked. Each question was associated with a 100-mm visual analog scale, which consisted of opposing statements. The average of the four scores, with the satisfaction and fullness question inverted, was used as an overall appetite score (Flint et al., 2000; Islam et al., 2017). Subjective appetite was assessed directly before, directly after, and one-hour after each exercise session.

Throughout the study, energy intake was estimated utilizing three-day food records. Participants were instructed to record their dietary intake on Sunday, Monday, and Tuesday of the first and final week of both exercise periods. These food records fell on weeks 1, 5, 7, and 11 of the study. This three-day approach included a weekday with exercise, a weekday without exercise, and a weekend day. Total caloric intake was averaged for the three recorded days and was calculated utilizing the computer program Cronometer (Cronometer Software Inc). Participants were asked to maintain their eating habits and not deviate during food recording.

Statistical analysis was performed with SPSS 25.0 (SPSS Inc., Chicago, IL). Statistical significance was set at $p < 0.05$. Repeated-measures ANOVA was used to calculate changes in subjective appetite and changes in body composition, weight, and energy intake over the duration of the study. Pairwise comparisons with Bonferroni corrected p-values to control for type 1 family-wise error rate were utilized to compare means between testing sessions.

Results

Baseline characteristics are presented in Table 1.

Table 1

Baseline Characteristics

Age (years)	22 ± 3.6
Body Mass (kg)	83.4 ± 14.8
Body Fat%	31.8 ± 10.6
BMI (kg/m2)	28.8 ± 3.6
WHR	0.8 ± 0.05
VO2max (ml/kg/min)	30.5 ± 9.3

Note. Results represented as mean ± SD.
WHR = Waist-to-hip ratio.

No chronic differences in subjective appetite were found either within or between interventions over the duration of the study. However, subjective appetite post-exercise was 5.7% higher (MICT VAS= 4.27 vs. HIIT VAS= 4.53, t= 5.508, 95% CI [2.4143, 6.6391] $p = .03$) on the first day of HIIT than it was in the first day of MICT. Mean appetite scores for before, directly after, and one-hour after for the first and final three sessions of both interventions can be viewed in Table 2.

Table 2

Subjective Appetite Score

VAS	Start of MICT	Finish of MICT	Start of HIIT	Finish of HIIT
Before	3.39 ± 1.7	4.91 ± 2.1	4.02 ± 1.7	4.2 ± 1.3
After	4.32 ± 1.42	4.23 ± 1.4	4.21 ± 1.9	4.41 ± 1.9
1-Hour	5.68 ± 1.8	5.38 ± 3.0	4.62 ± 1.6	5.20 ± 1.8

Note. Results represented as mean ± *SD*.

There was a significant effect of time on energy intake (Lambda = 0.58, $F(3,3) = 16.266$ $p = 0.023$), as it decreased in subjects over the duration of the study. Individual mean energy intake in weeks 1, 5, 7, and 11 are listed below in Table 3.

Table 3

Individual Energy Intake

Subject	1	2	3	4	5	6
Week 1	1351	2778	2443	3186	2438	1724
Week 5	1548	2144	2106	2765	2679	1681
Week 7	1201	1952	1703	2396	2343	1481
Week 11	1126	2028	1350	2804	1747	1614

Note. Energy intake reported as kcal.

Of the testing measurements, resting systolic blood pressure was the only measurement to improve significantly ($p = 0.027$). Mean results from the three testing sessions can be viewed in Table 4.

Table 4

Testing Measurements

Measure	Pre-testing	Post-testing 1	Post-testing 2	*P*-value
Body Mass (kg)	83.4 ± 14.8	82.5 ± 13.2	82.6 ± 14.1	1.000
Body Fat (%)	31.8 ± 10.6	32 ± 10.8	32.4 ± 11.0	1.000
Waist-to-Hip Ratio	0.8 ± 0.05	0.77 ± 0.06	0.76 ± 0.06	1.000
Resting HR (beats per minute)	68.8 ± 10.6	58.8 ± 10.7	74.8 ± 7.3	1.000
Resting BP Systolic (mmHg)	127.7 ± 11.1	125.7 ± 3.2	120.7 ± 3.14	0.027
Resting BP Diastolic (mmHg)	74.8 ± 10.4	77.2 ± 10.5	71.8 ± 10.2	0.057

Note. Results represented as mean ± SD. Reported from repeated measures ANOVA. *P*-values represent difference between Post-test 1 and Post-testing 2.

Discussion

This study compared the effects that repeated MICT and HIIT had on subjective appetite, energy intake, and body composition in overweight and sedentary adults. Repeated bouts of aerobic exercise, regardless of intensity, had no chronic impact on subjective feelings of hunger. However, when comparing the post exercise appetite between the first exercise session of each period, participants reported significantly higher feelings of hunger after HIIT. Energy intake within subjects was reduced over the duration of the study ($p = 0.023$). Body composition also did not improve over the duration of training as body fat percentage, waist-to-hip ratio, weight, and BMI was unchanged. Resting heart rate was unchanged between any of the three testing sessions. Resting systolic blood pressure did significantly improve ($p = 0.027$) during the HIIT protocol, and the diastolic blood pressure trended towards a significant improvement ($p = 0.057$).

While studies on the effect of chronic aerobic exercise on the obese and sedentary population are scarce the findings within them are highly variable. A 12-week study compared the effects MICT, HIIT, and another HIIT protocol designed to expend half the energy in sedentary and obese adults on subjective feelings of appetite. Unlike this experiment, individuals in all three exercises had increased subjective feelings of hunger both fasting and after consuming a meal after 12 weeks of exercise compared to baseline (Martins et al., 2017). In contrast to the current study, participants only had their subjective appetite measured before and after exercise. Participants in this study completed either MICT or HIIT for the duration of the study and completed 36 exercise sessions of just one protocol. The longer duration and use of only one exercise intensity per subject could explain the discrepancy in results. More time at different intensities may be needed to detect any meaningful changes.

Another study aimed to control for individual variation by breaking their participants into a compensation group and a non-compensation group. These groups were split based upon if the individuals met expected weight loss or not. Of the 35 participants, 18 did not meet expectations during the 12 week exercise program, and were labeled as compensators (King et al., 2008). Subjects labeled as compensators experienced a trend of increased hunger, while non-compensators had negligible changes. In contrast to our hypothesis, these studies showed trends towards an increase in hunger following repeated aerobic exercise. As highlighted in these studies' individual variation in combination with our small sample size may have contributed to us finding no changes in subjective appetite.

While our study found no chronic changes in appetite in contrast to other literature, we did find that our participants had a 5.7% greater ($p = 0.03$) appetite score on the on the first day of HIIT in comparison to MICT. These acute changes in appetite align better with results of the chronic studies listed previously. In an acute study comparing the effects of a single bout of HIIT, MICT, and short duration HIIT on subjective feelings of hunger, no changes in hunger or energy intake were found (Martins et al., 2015). While we found a difference in appetite acutely between MICT and HIIT, this could have been since our participants had five weeks of exercise performed before their first HIIT session. As in the chronic training studies, a study aimed to control for individual variability by labelling participants as either compensators or non-compensators (Finlayson et al., 2009). All individuals reported greater levels of hunger after 50 minutes of cycling at 70% maximum heart rate, which is very similar to our MICT protocol. Individuals labeled as compensators reported a higher preference for high-fat sweet foods in comparison to non-compensators, which could be one reason for high variability between individuals.

No change in energy intake might be expected as appetite did not change, and body composition was not improved. This would align with other research that repeated aerobic exercise seems to have little effect upon daily energy intake in the overweight population (King et al., 2008; Martins et al., 2017). However, our subjects did have reduced energy intake over the duration of their participation in exercise. We cannot conclude whether this was due to the combined effects of both MICT and HIIT, or the increase in intensity between the interventions. An acute study was performed where overweight men participated in four different trials of aerobic exercise, two of which were similar to our own MICT and HIIT sessions (Sim et al., 2014). Post exercise energy intake was reduced in the HIIT ($p = 0.038$), but unchanged in the MICT trial. This finding would support the idea that the increase in exercise intensity in the HIIT trial may have had positive effects on energy intake. Some studies have found no changes in energy intake over a similar amount of time (Martins et al., 2016). More chronic training studies comparing the effects of different aerobic exercise intensities of overweight and sedentary adults are needed.

We can also conclude that our exercise protocol was unable to cause meaningful changes to body composition as BMI, body fat percentage, weight, and waist-to-hip ratio went unchanged. Added dietary interventions may aid in weight loss but would make it more challenging to assess how exercise impacts energy intake and subjective eating behavior. However a recent meta-analysis comparing the effects of short-term MICT and HIIT on body composition in overweight adults found that both could improve body composition even without reductions in bodyweight (Wewege et al., 2017). There was also a large discrepancy between cycling and running interventions. Running had a large positive effect on body fat mass in both MICT and HIIT protocols while cycling had no effect. Among our small sample size, mode of exercise, and lack of dietary interventions could be reasons why improvements in body composition were not found.

While improvements in body composition were not found, participants did reduce their systolic blood pressure by 5 mmHg ($p = 0.027$) between post-testing 1 and post-testing 2. Diastolic blood pressure improved by 5.55 mmHg between post-testing 1 and post-testing 2 which trended towards a significant value ($p = 0.057$). This is an important finding as reduced systolic blood pressure is associated with lower rates of cardiovascular disease and all-cause mortality (Bundy et al., 2017). Therefore, even without improvements in body composition, participation in HIIT can improve biomarkers of health in overweight and previously sedentary adults.

Conclusion

No significant changes in subjective appetite were seen throughout MICT, HIIT, or the combination of the two protocols. However post-exercise feelings of appetite were increased in the first day of HIIT in comparison to MICT. Energy intake was reduced over the duration of the study; however, body composition did not significantly change over the duration of the study either. Blood pressure improved over the HIIT period as systolic blood pressure was significantly reduced, and diastolic trended towards a significant reduction. Exercise mode, duration of intervention, small sample size, and the trend for high individual variability could have negatively impacted our results. While 30 sessions of aerobic exercise, particularly HIIT, is enough to improve biomarkers of health, more research is needed to pinpoint how cardiovascular exercise interventions can best compliment weight loss in overweight and sedentary adults.

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CHAPTER V. SUMMARY

The purpose of this study was to examine changes in appetite, eating behavior, and body composition in overweight and sedentary adults after completing both repeated moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT) for multiple weeks. We completed this experiment in hopes of finding which intensity best supported weight loss in a population that could benefit from such a program. We were unable to find any significant changes in appetite, eating behavior, or body composition over the duration of participation. However, after looking at some of our secondary variables we identified a difference in post-exercise appetite between the first days of MICT and HIIT. Participants were significantly higher appetite scores after the first session of HIIT than MICT. Systolic blood pressure was also reduced between the finish of MICT and final testing session. Diastolic blood pressure trended towards a significant reduction at the same timepoint and may very well have been significant with a larger sample size. These improvements in blood pressure would indicate that aerobic exercise, especially HIIT, in the absence of body composition improvement can improve biomarkers of health.

Limitations of our study include generalizability as our sample was primarily undergraduate students in their early to mid-twenties recruited from an upper Midwest university. This study took place in the spring semester and due to university holidays and weather-related cancellations the HIIT took seven weeks to compete the exercise sessions in comparison to five weeks in the MICT. Our participants also had highly variable schedules and were unable to have each exercise session at the same time of day. This could impact the exertion of exercise and timing of meals around their sessions. Food records can be prone to mistakes as participants could easily report their food inaccurately and researchers could misinterpret those food records. Visual analog scales in nature are subjective and could be interpreted differently between subjects. We also had a small sample size of only six individuals, making our statistical power almost non-existent. Finally, participation in previous exercise or participants exercising outside of their laboratory visits could impact their response to our training.

Future research should look to investigate how aerobic exercise impacts eating behavior based upon different parameters than intensity and volume. Recommending exercise volume based upon resting metabolic rate could be useful and may potential mitigate the highly variable results in the current literature. Studies of longer than 12 weeks may be warranted, as a few months may not be a long enough time to induce changes in appetite and eating behavior. Additionally, investigation into the combined effects of aerobic exercise and resistance training on appetite as most health organizations recommend participation in both types of exercise.

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APPENDIX A. PHYSICAL ACTIVITY READINESS QUESTIONAIRE

2018 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:**	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:**	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:**	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION
If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness centre may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ____________________ DATE ____________

SIGNATURE ____________________ WITNESS ____________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ____________________

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm*

If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes*

If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

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6.	**Do you have any Mental Health Problems or Learning Difficulties?** *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome* If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7	
6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐
7.	**Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure* If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8	
7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐
8.	**Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia* If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9	
8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐
9.	**Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event* If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10	
9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐
10.	**Do you have any other medical condition not listed above or do you have two or more medical conditions?** If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations	
10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

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If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________ DATE ______________________

SIGNATURE ______________________ WITNESS ______________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

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3. Chisholm DM, Collis ML, Kulak LL, Davenport W, and Gruber N. Physical activity readiness. British Columbia Medical Journal. 1975;17:375-378.
4. Thomas S, Reading J, and Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Science 1992;17:4 338-345.

APPENDIX B. FOOD RECORD

Three Day Dietary Recall Day 1			
Time	Food / Drink	Amount	Special Note

APPENDIX C. SUBJECTIVE APPETITE SCALE

Subject ID Code: Date: **Before Exercise**

How hungry do you feel?

I am not hungry at all.	0 1 2 3 4 5 6 7 8 9 10	I have never been more hungry.

How satisfied do you feel?

I am completely empty.	0 1 2 3 4 5 6 7 8 9 10	I could not eat another bite.

How full do you feel?

Not at all full.	0 1 2 3 4 5 6 7 8 9 10	Totally full.

How much do you think you can eat?

Nothing at all.	0 1 2 3 4 5 6 7 8 9 10	A lot.