THE EFFECT OF EXERCISE INTENSITY ON PERCEIVED POST-EXERCISE APPETITE

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MASTER OF SCIENCE

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ABSTRACT

The purpose of this study was to investigate whether there is a greater reduction in appetite following a high intensity interval training (HIIT) exercise session compared to a steady-state exercise (SSE) exercise session**.**

Six subjects completed all three trials in a random, counterbalanced order, measuring subjects' perceived appetites throughout the trial. HIIT was 10 two-minute bouts of high-intensity exercise separated by one minute rest, SSE was 30 minutes moderate intensity exercise, and control was 40 minutes rest. Eleven visual analog scale (VAS) surveys were completed to measure perceived appetite and taste preferences.

HIIT significantly lowered appetite scores compared to the control trial immediately after exercise: "how hungry do you feel" ($p = 0.0476$); "how satisfied do you feel?" ($p = 0.0116$); "how full do you feel?" ($p = 0.0225$). No other significance was found. These results strengthen previous research that HIIT may lead to greater suppression of appetite immediately following exercise.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

GPAQ.....................................Global Physical Activity Questionnaire

HIIT..High Intensity Interval Training

HRM ....Heart Rate Maximum

IRB...Institutional Review Board

PAR-Q....................................Physical Activity Readiness Questionnaire

SSE...Steady-State Exercise

VAS..Visual Analogue Scale

CHAPTER 1. INTRODUCTION

4.5. Introduction to the Problem

The increasing prevalence of individuals who are overweight, obese, and extremely obese is a growing public health problem in the United States. Data from the National Health and Nutrition Examination Survey (NHANES) showed that the prevalence of obese adult (ages 20 or higher) Americans in 1960-1962 was 13.4% (Hensrud & Klein, 2006). Data from NHANES in 2003-2004 showed that 66.3% of adult Americans were overweight or obese (Hensrud & Klein, 2006). A more recent study showed that the prevalence of obesity seems to have leveled off, with no significant increases in prevalence between 2003-2004 and 2009-2010, however these numbers are still too high and obesity remains an issue (Ogden, Carroll, Kit, & Flegal, 2014). Obesity is defined as an excess of body fat (Hensrud & Klein, 2006). Body Max Index (BMI) is a common tool used to assess if an individual is overweight or obese. A BMI of 25-29.9 is considered overweight, and a BMI greater than 30 is classified as obese (Deighton, Zahra, & Stensel, 2012; Hensrud & Klein, 2006). Obesity that develops when energy intake exceeds energy expenditure over a long period of time (Deighton et al., 2012) highlights the importance of regular exercise. Low levels of physical activity, or a sedentary lifestyle, have been associated with an increased risk of obesity (Hensrud & Klein, 2006). It has been found that more than 60% of the U.S. population does not perform regular exercise or physical activity, and that 25% of the population is considered sedentary (Hensrud & Klein, 2006). One of the most common reasons stated for not exercising regularly is a “lack of time” (Trost, Owen, Bauman, Sallis, & Brown, 2002). When considering this along with the growing prevalence of obesity, it is important to find alternatives to the more traditional moderate aerobic exercise. Moderate aerobic, or steady-state exercise (SSE), consists of aerobic activity at a moderate intensity, usually done for about 60 minutes. An alternative to this traditional type of exercise is high-intensity interval training (HIIT). HIIT can be described as repeated bursts of relatively intense exercise separated by periods of rest or low-intensity exercise (Gillen & Gibala, 2013). HIIT sessions are relatively short in length, usually less than 30 minutes including a warm up and cool down (Gillen & Gibala, 2013), which makes HIIT a great alternative to SSE, especially for those with limited time for exercise.

Previous research has found that High-Intensity Interval Training (HIIT) can result in greater fat burning and weight loss than aerobic Steady State Exercise (SSE) (Boutcher, 2011; Gibala & McGee, 2008; Hottenrott, Ludyga, & Schulze, 2012; Whyte, Gill, & Cathcart, 2010). The exact mechanisms or physiological effects responsible for the greater fat loss and therefore weight loss in response to HIIT are not known. There are several different theories as to how HIIT can elicit these changes, one being that there could be a greater circulation of anorectic hormones as a result of HIIT which may lead to suppression of appetite and reduced food intake following exercise (Deighton, Barry, Connon, & Stensel, 2013; Deighton, Karra, Batterham, & Stensel, 2013). In previous research looking at appetite following HIIT, there have been mixed results. Some studies found that appetite was suppressed following HIIT while some found there was no significant difference in appetite following HIIT and SSE exercise sessions.

4.5. Purpose of this Study

The purpose of this study was to investigate whether there is a greater reduction in appetite following a HIIT exercise session compared to an SSE exercise session. Determining if there is a reduced appetite perception in HIIT compared to SSE could help us better understand the mechanisms responsible for the reduction of fat and weight as a result of HIIT, therefore help determine the effectiveness of HIIT as a weight loss exercise program.

4.5. Research Questions

- What are post-exercise appetite responses to two different intensities of exercise?
- Does HIIT lead to a greater suppression of appetite than SSE following exercise?
- Is there a preference for types of food (sweet, salty, savory, fatty) to be ingested following exercise of different intensities?

4.5. Limitations

- Subjects consisted of young healthy males. However this is important because there is such great variation in hormone levels and responses between males and females. Healthy subjects were chosen opposed to other populations due to the high-intensity, demanding nature of the HIIT trial.

4.5. Key Terms

Anorexigenic- having a suppressing effect on appetite (Aydin, 2014).

Appetite- includes various aspects of eating patterns such as frequency and size of eating episodes, choices of high fat or low fat foods, energy density of foods consumed, variety of foods accepted, palatability of diet and variability in day-to-day intake (Arora & Anubhuti, 2006).

Energy intake- food or beverage consumption or eating (Blundell & King, 2000).

Ghrelin- the only known orexigenic gut peptide, responsible for appetite stimulation (Deighton, Barry, et al., 2013).

High-intensity interval training (HIIT)- refers to repeated sessions of relatively brief intermittent exercise, often performed with an “all-out” effort or at an intensity close to that which elicits VO2max (greater or equal to 90% VO2max) (Gibala & McGee, 2008).

Leptin- protein hormone expressed by the obese gene, which plays a role in energy balance through control of appetite and energy expenditure. It is thought to have anorexigenic effect .

Neuropeptides- the most diverse class of signaling molecules in the brain engaged in many physiological functions (Burbach, 2011).

Orexigenic- having a stimulating effect on appetite (Aydin, 2014).

PYY_{3-36}- anorexigenic gut peptide, suppresses appetite (Deighton, Barry, et al., 2013).

Relative energy intake- energy intake minus the net energy expenditure of exercise (Deighton, Barry, et al., 2013).

Steady state exercise (SSE)- exercise at a moderate intensity, a more common and traditional protocol designed to induce fat loss (Boutcher, 2011)

VO2max- maximal oxygen uptake, a measurement of cardiorespiratory fitness (Boutcher, 2011).

CHAPTER 2. LITERATURE REVIEW

2.1. Purpose of the Study

The purpose of this study was to investigate if there is a greater reduction in appetite following a high-intensity interval training (HIIT) exercise session compared to a steady-state exercise (SSE) session. Determining if there is a reduced appetite perception following HIIT compared to SSE could help us better understand the mechanisms responsible for reduction of fat and weight as a result of HIIT, therefore help determine the effectiveness of HIIT as a weight loss exercise program.

2.2. Introduction

With the growing obesity epidemic, there has also been an increased prevalence of the metabolic syndrome, which includes cardiovascular risk factors such as high blood pressure, dyslipidemia, and insulin resistance (Bartlett et al., 2011). An effective way to combat this epidemic is through physical activity and exercise (Caudwell, Gibbons, Finlayson, Naslund, & Blundell, 2013). This seems like a simple cure, except that many people cite lack of time or lack of enjoyment as a reason for not engaging in exercise (Bartlett et al., 2011; Trost et al., 2002). The traditional exercise approach for reducing weight has been continuous aerobic, or steady-state exercise (SSE). This requires individuals to continually exercise at a sub-maximal intensity for long periods of time, usually 30-60 minutes. However, another approach called high-intensity interval training (HIIT) may be a more favorable method that has the ability to produce the same, if not greater, benefits as SSE. HIIT can be described as repeated bursts of relatively intense exercise separated by periods of rest or low-intensity exercise (Gillen & Gibala, 2013).

There are many physiological effects and mechanisms involved with HIIT, but the focus of this review will be on those involved with the regulation of appetite. In order to understand if

HIIT is an effective method to elicit the same or greater benefits than SSE, it is important to have a better understanding of all physiological effects and mechanisms that are involved.

2.3. What is HIIT?

As stated previously, HIIT can be described as repeated bursts of relatively intense exercise separated by periods of rest or low-intensity exercise (Gillen & Gibala, 2013). Most commonly, HIIT sessions are performed on a stationary cycle ergometer at an intensity of at least 90% of VO2max or higher, but can be done using different modes or intensities of exercise (Boutcher, 2011). There are different forms of HIIT, one being low-volume HIIT. This refers to exercise sessions that are relatively short in length, less than 30 minutes including warm up and cool down, but require very intense bouts (Gillen & Gibala, 2013). A popular example of low-volume HIIT would be repeated bouts of the Wingate Test. The Wingate Test consists of 30 seconds of all-out effort against high resistance on a specially designed bike (Gillen & Gibala, 2013). HIIT sessions using the Wingate Test usually include four to six 30 second bouts separated by about four minutes of recovery (Boutcher, 2011; Gillen & Gibala, 2013). However, for most populations this can be very taxing and may lead to nausea, along with a very high risk of injury. Because of this, low-volume HIIT training can be modified to make it more safe and attainable for a greater variety of populations.

Modifying HIIT makes this type of training more feasible for different populations while still remaining time-efficient compared to other types of training, and still stimulating adaptations similar to more demanding low-volume HIIT (Gillen & Gibala, 2013). There are many different ways HIIT can be modified. One example consists of 10 sets of one minute cycling bouts at about 85-90% of VO2max, with one minute of recovery between each bout (Gillen & Gibala, 2013). This sums up to 10 minutes of vigorous exercise and 25 minutes of total exercise including a warm-up, recovery periods between bouts, and a cool-down, making it still relatively time-efficient. This model has been employed in studies of young healthy individuals, overweight/obese individuals, older sedentary adults at higher risk for cardiometabolic disorders, and patients with coronary artery disease and type 2 diabetes (Gillen & Gibala, 2013). Another model of HIIT includes a modified Wingate-based protocol consisting of four sets of 10 second all-out sprints, which leads to improvements in aerobic and anaerobic performance (Hazell, Macpherson, Gravelle, & Lemon, 2010). Another HIIT protocol consisted of an eight second cycle sprint followed by 12 seconds of low-intensity cycling for a total of 20 minutes (Boutcher, 2011). This came out to a total of 60 sprints, or eight minutes of sprinting, and 12 minutes of low-intensity cycling.

Modifying HIIT can also include combining short, high-intensity bouts with longer bouts of low-intensity exercise. For example, one study added two sets of 20 second all-out sprints within a 10 minute bout of low-intensity cycling (Metcalfe, Babraj, Fawkner, & Vollaard, 2012). In this protocol, there was only 40 seconds total of all-out, high-intensity exercise, but significant improvements were still seen in VO2max after six weeks of training despite the short duration of exercise sessions (Metcalfe et al., 2012). Although cycling is the most common form of exercise used, HIIT can be performed using other modes of traditional exercise such as climbing stairs, running, or skipping rope (Gillen & Gibala, 2013; Kawano et al., 2013). One study had subjects train using eight sets of 20 seconds of a single exercise (burpees, jumping jacks, mountain climbers, or squat thrusts) with 10 seconds of rest between each bout four times a week for four weeks. Results showed that VO2max was increased to the same extent as a group who performed 30 minutes of traditional endurance training four times a week for four weeks (Gillen & Gibala, 2013).

The previously described HIIT protocols are only a few examples, and there is no universal HIIT protocol. While HIIT can be modified for time, duration, and mode of exercise, HIIT can also be modified in terms of exercise intensity. An individual can develop their own HIIT exercise protocol or program to fit their needs as long as some basics are included. In order to be considered high-intensity, bouts should be done to elicit around 90% of VO2max or higher (Gibala & McGee, 2008). This is easy in a laboratory setting; however, for the general population that doesn't have access to the necessary equipment, it may be hard to determine a percentage of VO2max. Another way to determine if intensity is high enough to be considered HIIT is to look at heart rate (Kravitz, 2014). High intensity interval work should be done at 80% or greater of maximal heart rate, which can easily be calculated (Kravitz, 2014). General populations can also use the "talk test" as a guide. When performing high-intensity exercise, an individual should not be able to carry on a conversation or talk without great difficulty (Kravitz, 2014). For the recovery intervals between bouts, individuals can choose an active or inactive recovery. An inactive recovery would be no exercise at all. If choosing to do an active recovery between bouts, intensity should be at about 40%-50% of max heart rate (Kravitz, 2014). When considering implementing HIIT, it is important to undergo proper screening procedures as well as obtain medical clearance, especially for those that are at a higher risk of or have chronic conditions such as diabetes or cardiovascular disease (Gillen & Gibala, 2013). It is also important to establish a basic level of fitness before introducing HIIT into an exercise program and to introduce HIIT slowly to reduce risks associated with exercise-induced ischemic events (Gillen & Gibala, 2013).

2.4. Benefits of HIIT

One of the important factors as to why HIIT may be a favorable alternative to SSE is that it can be far more time-efficient. Since lack of time is a major barrier to exercise for the general population, HIIT offers an alternative method to exercise when there is a limited amount of time (Gibala & McGee, 2008; Gillen & Gibala, 2013). As stated in the previous section, HIIT sessions can last as little as 10 minutes depending on the protocol chosen. Although HIIT may be perceived as much more strenuous than SSE, the small amount of time required makes it an enticing option for individuals trying to improve fitness and health (Gibala & McGee, 2008).

HIIT has been shown to improve aerobic and anaerobic fitness, cardiovascular health, blood pressure, insulin sensitivity, cholesterol profiles, and abdominal fat and body weight (Gibala & McGee, 2008; Gillen & Gibala, 2013; Hottenrott et al., 2012; Whyte et al., 2010). HIIT has also been shown to rapidly improve exercise capacity. One study found that subjects doubled the length of time that exercise could be maintained at a fixed submaximal workload, improving from 26 to 51 minutes while cycling at 80% of VO2max, while a control group showed no change (Burgomaster, Hughes, Heigenhauser, Bradwell, & Gibala, 2005). These improvements occurred after only six HIIT sessions over a two week period. Other work also confirmed that two weeks of Wingate-based HIIT training improved performance in tasks that more closely resembled athletic competition, such as timed trials and stimulated cycling races lasting from two minutes to one hour (Burgomaster, Heigenhauser, & Gibala, 2006). However, there were no changes in VO2max, suggesting that peripheral adaptations may have been largely responsible for improved exercise capacity (Burgomaster et al., 2006).

Aerobic fitness level has been established as a strong predictor of cardiovascular and all-cause mortality. In a 16 year follow-up study, it was found that a single weekly bout of high-intensity exercise reduced the risk of cardiovascular death in both men and women, compared with those who reported no activity (Wisløff, Ellingsen, & Kemi, 2009). Studies have also shown that HIIT may lead to more cardiovascular benefits than SSE. One study showed that relative peak oxygen uptake was improved by 18.6% in a group that performed high-intensity interval training compared to only 7.1% in a group that performed continuous aerobic exercise following a 12 week trial (Hottenrott et al., 2012). The previous study compared SSE, consisting of two sessions a week totaling two and a half hours, to HIIT consisting of four sessions and one short aerobic session equaling two and a half hours. Along with improvements in VO2max in the HIIT group, both groups showed significant reductions in resting heart rate (Hottenrott et al., 2012). It was also found that after two weeks consisting of six sessions of the Wingate-based HIIT, sedentary overweight/obese subjects significantly improved VO2max and significantly reduced systolic blood pressure (Whyte et al., 2010). Improving VO2max is an important health benefit in that it allows greater adaptations to the oxygen delivery system through increased stroke volume and cardiac output, allowing the heart to work more efficiently (Hottenrott et al., 2012). Lowering resting heart rate is also an important benefit because the heart doesn't have to work as hard to deliver blood to the rest of the body (Hottenrott et al., 2012). By using sedentary overweight/obese subjects, Whyte et al. (2010) further demonstrated that HIIT could be an effective training method for a variety of populations.

Another benefit of HIIT is the reduction of body fat and improvements in body composition. HIIT has been shown to increase catecholamines, specifically epinephrine, which have been shown to drive lipolysis and are largely responsible for fat release from both subcutaneous and intramuscular fat stores (Boutcher, 2011). Also, more β-adrenergic receptors, which bind with epinephrine, have been found in abdominal fat compared to subcutaneous fat, suggesting that HIIT may be able to lower abdominal fat stores (Boutcher, 2011). This is evident in the study by Hottenrott et al. (2012) as they found that although there was no significant reduction of fat-free mass or total body fat in the HIIT group, visceral fat was significantly decreased by 16.5%. Whyte et al. (2010), utilizing sedentary overweight/obese men, found that after two weeks of HIIT there was a tendency for body mass to be lower, and waist and hip circumferences were modestly but significantly reduced.

There are several skeletal muscle adaptations that may take place in response to HIIT. It has been consistently found that there is an increase in muscle oxidative capacity ranging from about 15% to 35% after six sessions of HIIT training over a two week period (Burgomaster et al., 2006; Burgomaster et al., 2005; Gibala & McGee, 2008). A study comparing six sessions of a standard HIIT protocol versus six sessions of continuous cycling at 65% VO2max for 90-120 minutes found very similar adaptations in exercise performance and skeletal muscle oxidative capacity (Gibala et al., 2006). The significance in these findings are that similar adaptations were found even though the HIIT group only exercised approximately two and a half hours over the two week period while the SSE group performed about 10.5 hours of exercise.

Another change that has been found in skeletal muscle following HIIT deals with carbohydrate metabolism. Changes in carbohydrate metabolism normally seen with traditional endurance training such as increased resting glycogen content, a reduced rate of glycogen utilization and lactate production during matched-work exercise, and increased total muscle glucose transporter-4 protein content, have been seen following only two weeks of HIIT (Burgomaster et al., 2007; Burgomaster et al., 2006; Gibala & McGee, 2008). Increases in resting muscle glycogen content are important because skeletal muscle primarily relies on glycogen in order to perform high-power outputs (Burgomaster et al., 2007), so an increase would result in greater ability to perform higher-powered outputs for a greater duration. The glycogen used by muscle during exercise, especially intense exercise, is mainly converted into lactate. Large amounts of lactate accumulate and therefore increases hydrogen ions (H^+), which creates a challenge in systems that regulate muscle pH (Burgomaster et al., 2007), causing individuals to fatigue faster. Therefore, HIIT can provide a reduction in lactate production which can delay the onset of fatigue (Burgomaster et al., 2007; Burgomaster et al., 2006). Performing HIIT over several weeks induces changes in monocarboxylate transporter (MCT) proteins that regulate lactate and H^+ exchange in human skeletal muscle (Burgomaster et al., 2007), which could explain why reduced rates of lactate production have been found in these studies.

A six week study compared four to six Wingate Tests with four and a half minute breaks per session three days a week to 40-60 minutes continuous cycling at about 60% VO2max per session five times a week (Burgomaster et al., 2008). It was found that both protocols induced similar increases in mitochondrial markers for skeletal muscle carbohydrate and lipid oxidation despite much lower time commitment in the Wingate group. This same study found that while there were no differences between groups, calculated rates of whole-body carbohydrate oxidation was decreased while lipid oxidation was increased (Burgomaster et al., 2008). This decrease in carbohydrate oxidation and increase in lipid oxidation means that more fat was being used as fuel, therefore more fat was being burned. Although there was no significant difference in these improvements between the groups, the HIIT, or Wingate, group acquired these changes with far less exercise duration than the SSE group, further demonstrating the efficiency of HIIT.

Another benefit of HIIT is the possibility that it can result in increased insulin sensitivity. Someone who is insulin sensitive will require smaller amounts of insulin to lower blood glucose levels, while someone that is insulin resistant will have a reduction in insulin-mediated glucose uptake, which is a risk factor for type 2 diabetes and coronary heart disease (O'Donovan, Kearney, Nevill, Woolf-May, & Bird, 2005). Therefore, increasing insulin sensitivity is beneficial. Two weeks of sprint interval training in sedentary overweight/obese males found that insulin sensitivity was significantly increased following the intervention (Whyte et al., 2010). Another study reported that insulin sensitivity was also significantly increased in healthy young men after two weeks of sprint interval training (Babraj et al., 2009). O'Donovan et al. (2005) found that after 24 weeks of training, both a moderate intensity and HIIT group not only increased insulin sensitivity, but decreased insulin resistance significantly. Although there was no significant difference between the increases in insulin sensitivity and decreases in insulin resistance between the two groups, these results yet again support the idea that HIIT is a more time-efficient method to produce health benefits.

Not only does HIIT elicit many benefits, but it has also been found to be more enjoyable than SSE. In a study comparing HIIT to moderate-intensity SSE that were matched for duration, distance run, average intensity, and total oxygen consumption and energy expenditure, results showed that subjects' ratings of perceived enjoyment were significantly higher in the HIIT trial than the SSE trial (Bartlett et al., 2011). These results were found even though ratings of perceived exertion were also significantly higher in the HIIT trial. Subjects reported that the continuous aerobic exercise was "boring" while the varied nature of HIIT made exercise more enjoyable (Bartlett et al., 2011). Besides the many health benefits seen with HIIT, these results support that HIIT may be a more favorable and enjoyable method of exercise. Along with the fact HIIT trials require less time, HIIT may increase exercise compliance in individuals who are trying to be more active.

2.5. Neuropeptides, Appetite and HIIT

There are numerous central and peripheral neuropeptides, including orexigenic and anorexigenic, involved with the regulation of appetite (Arora & Anubhuti, 2006). The main focus here will be on some of the peripheral neuropeptides, including ghrelin, peptide YY (PYY_{3-36}), and leptin. One of the more recently discovered neuropeptides involved with appetite is ghrelin, which is the only known peripheral orexigenic gut peptide (Deighton, Barry, et al., 2013). Ghrelin is a 28-amino acid peptide mainly produced in endocrine cells (Arora & Anubhuti, 2006). There are two forms of ghrelin in the circulation, acylated and des-acylated (unacylated) ghrelin (Vatansever-Ozen, Tiryaki-Sonmez, Bugdayci, & Ozen, 2011). Although only 10-20% of ghrelin circulates in the acylated form, this is thought to be the form responsible for appetite stimulation (Arora & Anubhuti, 2006; Deighton, Barry, et al., 2013; Vatansever-Ozen et al., 2011).

The first study to publish data on the acute effects of exercise on circulating acylated ghrelin was done in 2007, and found that plasma acylated ghrelin was significantly lower during and immediately after running on a treadmill for 60 minutes at 72% of VO2max after an overnight fast (Broom, Stensel, Bishop, Burns, & Miyashita, 2007). The same study also found that subjective ratings of hunger were significantly reduced over the first three hours after the exercise trial, which was positively associated with suppressed acylated ghrelin. This suggested that moderate to high-intensity running may have the ability to suppress appetite. A study comparing 60 minutes of continuous cycling at 65% VO2max (SSE group) and six Wingate tests separated by four minutes each (HIIT group) found that the HIIT trial induced a greater suppression of appetite and acylated ghrelin during and immediately after exercise (Deighton, Barry, et al., 2013). However, the HIIT group resulted in compensatory increases in appetite (but not food intake) in the hours after exercise. The difference in exercise intensities in the HIIT trials between these two studies may have played a role in the contradicting results for appetite. Deighton, Karra et al. (2013) referred to the possibility that there may be a threshold of exercise intensity for the stimulation of appetite following exercise.

PYY_{3-36} is a gut hormone that reduces appetite and energy intake by modulating appetite circuits in the hypothalamus (Batterham et al., 2003). Following food intake, PYY_{3-36} is released into the circulation and peak plasma levels are seen postprandially after one to two hours (Arora & Anubhuti, 2006). Administration of PYY_{3-36} causes a delay in gastric emptying, a delay in secretions from the pancreas and stomach, and increases in the absorption of fluids and electrolytes from the ileum after a meal (Arora & Anubhuti, 2006). A study including healthy and obese individuals examined the effects of PYY_{3-36} infusion on energy intake compared to a placebo trial and found that there was an increased inhibition of appetite and food intake in both lean and obese individuals, which supports the evidence that PYY_{3-36} is an anorectic hormone and can lead to weight loss (Batterham et al., 2003).

There is a body of evidence that indicates that PYY_{3-36} concentrations are elevated during and immediately after strenuous exercise (Cheng, Bushnell, Cannon, & Kern, 2009; Deighton, Barry, et al., 2013; Deighton, Batterham, & Stensel, 2014; Deighton, Karra, et al., 2013; Kawano et al., 2013). Both SSE and HIIT elevate the concentrations of PYY_{3-36} following exercise trials, but concentrations were higher in the SSE trial than the HIIT trial immediately after exercise, even though appetite suppression was greater in the HIIT trial (Deighton, Barry, et al., 2013; Deighton, Karra, et al., 2013). However, Deighton, Karra, et al. (2013) found that in the hours after exercise, PYY_{3-36} concentrations were higher in the HIIT trial. It is thought that increases in PYY_{3-36} concentrations are related to increases in sympathetic nervous system activity, which increases with exercise intensity, and would explain the prolonged increase in PYY_{3-36} in the HIIT trial (Deighton, Karra, et al., 2013). However this would not explain why concentrations were lower in the HIIT trial immediately following exercise. A possible explanation for this is that there is decreased intestinal blood flow as exercise intensity increases, which may have reduced the transport of PYY_{3-36} into peripheral circulation immediately following exercise in the HIIT trial (Deighton, Karra, et al., 2013). Although PYY_{3-36} is known to suppress appetite, conflicting results in research that showed suppressed appetite but not higher concentrations of PYY_{3-36} immediately following a HIIT trial suggests that appetite is not solely dependent on PYY_{3-36} (Deighton, Barry, et al., 2013; Deighton, Karra, et al., 2013).

Another hormone involved in appetite regulation is leptin, which is the protein hormone expressed by the obese gene, playing a major role in energy balance . Leptin is a complex hormone to understand. Leptin produces counteractive and stimulatory mechanisms in relation to appetite. When fat mass decreases, so do plasma leptin levels, stimulating appetite to compensate for the loss of fat. Conversely, if fat mass increases, plasma leptin levels also increase to suppress appetite until weight loss occurs (Melzer, Kayser, Saris, & Pichard, 2005). However, research has shown that a majority of obese individuals are hyperleptinemic, suggesting that obesity is a condition of leptin resistance . Olive & Miller (2001) noted that plasma leptin concentrations were reduced following 60 minutes of moderate aerobic training while a short, high-intensity training bout had no effect on plasma leptin. This may indicate that there will be an increase in appetite following the moderate aerobic training, but not in the high-intensity training, which supports evidence that HIIT doesn't elicit compensatory energy intake following exercise (Deighton, Karra, et al., 2013). However, when dealing with an obese population that already have high levels of leptin, decreasing leptin initially may be an important factor. Because many obese individuals are resistant to leptin's actions, decreasing leptin levels with continuous aerobic exercise could increase the effectiveness of leptin receptors, allowing leptin to function in the correct manner. This highlights the complex nature of leptin.

2.6. Exercise Intensity and Energy Intake/Appetite

The mechanisms regarding appetite previously discussed may lead to a suppression of appetite following exercise, known as exercise-induced anorexia (King, Wasse, & Stensel, 2013; Melzer et al., 2005). There has been conflicting research regarding whether this exercise-induced anorexia leads to increases in energy intake or not. Understanding the appetite responses to exercise, especially exercise at different intensities, is important to determine the most effective method to create a negative energy balance without stimulating compensatory increases in appetite (Blundell & King, 2000). It is important to understand that as energy expenditure increases, food intake often increases as well, but this can be a very complex process (Melzer et al., 2005). It appears that short-term exercise (one to two weeks) doesn't necessarily stimulate compensatory energy intake, but after exercising in the long-term (several weeks or months), the body begins to make adjustments and increase energy intake in response to energy expenditure because a continual loss of body mass isn't favorable or possible (Blundell & King, 2000; Melzer et al., 2005). Especially when looking at a more athletic or active population, it is crucial to eat the necessary amount of food to allow the body to perform at its highest capability (Melzer et al., 2005).

For obese populations trying to lose weight, there should be a negative energy balance, meaning energy expenditure exceeds energy intake (Melzer et al., 2005). When implementing exercise, it is important to look at energy intake in terms of relative energy intake. Relative energy intake is the energy intake minus the net energy expenditure of exercise (Schubert, Desbrow, Sabapathy, & Leveritt, 2013). Looking at relative energy intake is an important component because although an individual may eat more following exercise compared to no exercise, when energy expenditure is accounted for there may still be a negative energy balance. It should also be noted that appetite and energy intake have two different meanings. Appetite deals more with various eating patterns such as the frequency and size of eating episodes and the desire to eat, while energy intake is how much food an individual actually consumes (Arora & Anubhuti, 2006). An increase in appetite does not necessarily mean there will be an increase in energy intake. This was demonstrated by Deighton, Barry et al. (2013) who found that while appetite increased to a greater extent in the HIIT group compared to the SSE group in the later hours of recovery after exercise, energy intake did not differ between the two groups.

It has been found that appetite is suppressed during and immediately following exercise of moderate-intensity or higher, but several studies found that appetite was suppressed to a greater extent during and immediately following exercise of a HIIT nature (Deighton et al., 2014; Deighton, Karra, et al., 2013; Kawano et al., 2013; Vatansever-Ozen et al., 2011). However, in all of these studies, appetite remained suppressed for only a couple hours post-exercise at most and returned to normal or higher levels later in the day. Although appetite sensation increased in the recovery period following exercise in one of these studies, appetite was significantly lower in the exercise trial than in the control trial where no exercise was performed (Vatansever-Ozen et al., 2011). Along with appetite, many of these studies also looked at energy intake in response to exercise. Although it may be expected that absolute energy intake would be increased following exercise, especially that of a HIIT nature, several studies found that there were no differences between absolute energy intake in exercise trials compared with a control trial (Deighton, Barry, et al., 2013; Deighton, Karra, et al., 2013; Vatansever-Ozen et al., 2011). These same studies also found that there was a lower relative energy intake in the exercise trials than in the control trials. When comparing relative energy intake between SSE and HIIT, results are more varied. Research has showed nine out of 12 participants having a lower relative energy intake following SSE compared to HIIT (Deighton, Barry, et al., 2013) and seven out of 12 participants having a lower relative energy intake following SSE compared to HIIT (Deighton, Karra, et al., 2013). A meta-analysis of studies looking at energy intake in response to exercise found that the median energy intake of the 29 included studies was 2017 kJ while the median energy expenditure was 2060 kJ, which suggests that the energy loss created by exercise is not being compensated for by a change in energy intake (Schubert et al., 2013). The 29 studies included a total of 51 different exercise trials, 26 of those trials being done at exercise intensities between 70% and 80% of VO2max (Schubert et al., 2013). While this range of intensity isn't quite high enough to be considered HIIT exercise, it is higher than what moderate-aerobic activity is usually considered.

A study done by King and colleagues (2013) assessed the amount of time it took after exercise for subjects to eat their lunch meal. Results showed that nine out of 10 participants had a greater delay in eating their meal following exercise than in the control trial, eating the meal about 35 minutes later (King et al., 2013). The exercise performed in this study was 60 minutes of running at 70% VO2max, which is considered moderate aerobic exercise. Although a HIIT trial wasn't included, this study supports that mechanisms responsible for the suppression of appetite in response to exercise may have played a role in the feeding latency of the exercise group. The previously described evidence that HIIT may lead to greater suppression of appetite following exercise indicates that feeding latency could be to a greater extent if the study by King et al. (2013) was of a more high-intensity nature.

2.7. Pre-Exercise Food Intake

Exercising in the fasted state has been proposed to be more beneficial for weight loss because it enhances fat oxidation (De Bock et al., 2005; Febbraio, Chiu, Angus, Arkinstall, & Hawley, 2000). However, there is more recent evidence that suggests exercising in the postprandial state may be more favorable because of its effects on appetite regulation and resting metabolism (Deighton et al., 2012). It was demonstrated that there was a more prolonged suppression of hunger following 50 minutes cycling at 60% of VO2max when exercise was performed after consumption of a high fat breakfast (Cheng et al., 2009). It was also found that post-meal appetite was suppressed to a greater degree after postprandial exercise compared to exercise in the fasted state (Borer, Wuorinen, Chao, & Burant, 2005). Although De Bock et al. (2005) and Febbraio et al. (2000) found that exercise in the fasted state led to greater fat oxidation during exercise, the evidence from Cheng and colleagues points to the possibility that consuming food prior to exercise may be more beneficial for appetite regulation through the course of the day.

2.8. Measuring Appetite

Most research that has measured appetite in response to exercise has used the Visual Analogue Scale questionnaire, or VAS (Deighton, Barry, et al., 2013; Deighton, Karra, et al., 2013; Kawano et al., 2013; King et al., 2013; Vatansever-Ozen et al., 2011). The VAS is an tool consisting of a question followed by a line, usually 100 millimeters in length, with words anchored on each end to describe the extremes that an individual may be feeling (Flint, Raben, Blundell, & Astrup, 2000). An example would be the question "How hungry are you?" followed by a 100 millimeter line with the word anchor "I am not hungry at all" on the left and "I have never been more hungry" on the right. The subject places a vertical mark on the line that correlates with how hungry they feel. The distance is then measured in millimeters from the left of the line to the mark the subject placed, and the distance in millimeters is recorded as their score. The VAS is often used in pain research and is considered the “gold standard” for measuring an individual’s level of pain (Flint et al., 2000). To validate the use of the VAS for measuring appetite, a study on the reproducibility, power, and validity of the VAS in assessment of appetite found that although there was a large variation of repeatability coefficients, appetite ratings using the VAS can be reproduced and used to measure appetite (Flint et al., 2000). The study concluded that with-in subject comparisons are more sensitive and accurate, so the number of subjects needed when using a VAS to measure appetite can be reduced when using paired designs. The study also concluded that all appetite parameters seem to explain subsequent energy intake to a certain degree.

2.9. Summary

Based on all the previous evidence, HIIT appears to be a more beneficial method of training compared to the traditional SSE. Not only has HIIT been shown to lead to the same or greater improvements on many health markers when compared to SSE, but it also does so in a smaller amount of time. Although the exact mechanisms responsible for all the benefits of HIIT are unknown, there is increasing evidence showing a relationship between HIIT and a suppression of appetite. A suppression of appetite following HIIT could play a role in the decrease in body fat, and therefore weight reduction, seen following HIIT programs. Since HIIT has also been found to be more enjoyable than SSE and again requires a smaller time commitment, HIIT can increase compliance to a workout regimen among individuals. All of these factors are important in combatting the increasing obesity epidemic. By investigating the role appetite plays in the weight loss seen following HIIT, we can further support the use of HIIT as an effective weight loss method.

CHAPTER 3. METHODS

3.1. Purpose of the Study

The purpose of this study was to investigate if there is a greater reduction in appetite following a high-intensity interval training (HIIT) exercise session compared to a steady-state exercise (SSE) session.

3.2. Introduction to Methods

To gain a better understanding of the effects different intensities of exercise have on appetite, this study had subjects perform a HIIT and SSE protocol and assess subjects' appetite responses. Determining if there is a reduced appetite perception in HIIT compared to SSE could help us better understand the mechanisms responsible for reduction of fat and weight as a result of HIIT. This would help to support the use of HIIT over SSE in individuals trying to maintain or lose weight.

3.3. Subjects

Subjects consisted of six healthy males ages 18-28. The goal was to get 15 subjects. After recruiting from many university classes, 26 individuals signed up stating they were interested in participating in the study. However six is the number of subjects who participated after many of the individuals did not respond to follow up emails or decided not to participate. Inclusion criteria for the subjects required that they engaged in regular aerobic exercise and did so for at least six months previous to the study. Regular aerobic exercise was considered at least 150 minutes of moderate-intensity exercise per week, which could be achieved by 30-60 minutes of moderate intensity exercise five days per week or 20-60 minutes vigorous exercise three times per week (Garber et al., 2007). Subjects were also non-smokers, maintained a stable weight for six months prior to the study, and weren't on any type of calorie-restricted diet. The physical characteristics of the subjects (mean ± SD) were as follows: age, 20.2 ± 0.75 years; height, 181.1 ± 9.4 cm; weight, 81.2 ± 1.7 kg; body fat percentage, 7.9 ± 1.6%.

3.4. Procedures

3.4.1. Familiarization

At the initial meeting, subjects were informed of testing protocol and familiarized with all testing equipment. If subjects chose to participate, they read and signed an informed consent. The study was approved by the university's Institutional Review Board (Appendix A). Subjects then completed a Global Physical Activity Questionnaire, or GPAQ, (Appendix B) and physical activity questionnaire (Appendix C) to determine that they were healthy enough to participate in the study and to determine current physical activity level.

3.4.2. Main Trials

Following familiarization, the study consisted of three trials; HIIT trial, SSE trial, and a control trial. Each trial was separated by 4 days. All subjects reported to the lab in the morning following an overnight fast of at least 12 hours. Subjects were also instructed to abstain from alcohol and physical activity for at least 48 hours prior to testing trials. For 24 hours prior to the first main trial, subjects filled out a food log (Appendix D) everything they consumed the day prior and were instructed to replicate this food intake as closely as possible for the 24 hours prior to the remaining two main trials. Once subjects arrived at the lab, they consumed one cup of low-fat chocolate milk. 30 minutes following consumption of the chocolate milk, the exercise portion of the trial began. Subjects also consumed another cup of low-fat chocolate milk immediately following the exercise portion of each trial. A percentage of maximum heart rate will be used to determine and monitor exercise intensity during main trials. To determine maximum heart rate (HRM), the equation 220-age was used. A percentage of HRM was then used to determine heart rate ranges for the different intensities in each trial.

3.4.3. Pre-Testing

During the 30 minutes between drinking their first cup of chocolate milk and starting the exercise portion of the trials, pre-test measurements were taken. Subjects were weighed and body fat was assessed using a seven-site skinfold measurement.

3.4.4. HIIT Trial

For the HIIT trial, participants performed a five minute warm up that consisted of light jogging, followed by 10 two-minute intervals running within the range of 90%-95% of HRM. Each interval was separated by one minute of rest. Subjects then completed a five minute recovery which consisted of walking at a comfortable pace. Heart rate was monitored to ensure that subjects performed high-intensity intervals in the appropriate intensity range.

3.4.5. SSE Trial

For the SSE trial, participants performed a five minute warm up that consisted of a light jog, followed by 30 minutes running within the range of 68%-72% HRM. Subjects then completed a five minute recovery which consisted of walking at a comfortable pace. Heart rate was again monitored to ensure that subjects ran within the appropriate range for the entire duration of the trial.

3.4.6. Control Trial

Instead of performing exercise, subjects sat and rested for 40 minutes.

3.4.7. Appetite Surveys

Subjects filled out visual analogue scale (VAS) questionnaires (Appendix E) throughout the study to measure their perceived appetite. VAS questionnaires were filled out after the subject consumed their first cup of chocolate milk, immediately prior to the start of exercise (or the start of the control trial), immediately after exercise ended (or the end of the control trial), and then every 30 minutes for four hours following the end of the exercise/control protocol. This resulted in a total of eleven VAS questionnaires filled out for each subject in each trial.

3.5. Research Design

The research design for this study was a counterbalanced Latin square design. Subjects performed each of the three trials in a randomly assigned sequence. The sequence of the order that each subject performed each trial was equally represented.

3.6. Statistical Analysis

A repeated measures ANOVA was used to assess differences in appetite scores between trials and time points. When significance was found at a specific time point, a Tukey pairwise comparison was used to determine which trials were significantly different. Significance was accepted as $p < 0.05$.

CHAPTER 4. THE EFFECT OF EXERCISE INTENSITY ON PERCEIVED APPETITE POST-EXERCISE[1]

4.1. Introduction

Obesity rates in the United States have grown to alarming figures. Data from NHANES in 2003-2004 showed that 66.3% of adult Americans were overweight or obese (Hensrud & Klein, 2006). Although more recent stats have shown the prevalence of obesity has leveled off since 2004, these numbers are still too high and obesity remains a serious issue (Ogden, Carrol, Kit, & Flegal, 2014). One reason for the increase in obesity is the lack of engagement in exercise (Hensrud & Klein, 2006). One of the most commonly cited reasons amongst individuals for not engaging in exercise is limited time (Trost et al., 2002). In order to combat the obesity epidemic, it is necessary to find the most time efficient and effective exercise method to increase exercise engagement among the population.

The traditional exercise approach for weight loss has been steady-state exercise (SSE), or exercising continually at a moderate intensity for a prolonged period of time. This has often been prescribed by doctors to patients looking to lose weight through exercise and has shown to be effective (Deighton, Barry, et al., 2013; Deighton, Karra, et al., 2013). However, SSE requires a larger chunk of time, which is undesirable for most people. A more recent alternative exercise approach to weight loss is high-intensity interval training, or HIIT. HIIT is repeated bouts of exercise done at a high or extremely high intensity, separated by short bouts of rest of

[1] The material in this chapter was co-authored by Megan Groen and Donna J. Terbizan. Megan Groen had primary responsibility for recruiting subjects and collecting data during trials. Megan Groen was the primary developer of the conclusions that are advanced here. Megan Groen also drafted and revised all versions of this chapter. Donna J. Terbizan assisted with data collection and served as proofreader. Ardith Brunt and Harlene Hatterman-Valenti also served as proofreaders.

low intensity exercise (Gillen & Gibala, 2013). HIIT has also been shown to be very effective, sometimes even more so than SSE, and requires far less time commitment (Boutcher, 2011; Gibala & McGee, 2008; Hottenrott, Ludyga, & Schulze, 2012; Whyte, Gill, & Cathcart, 2010).

Although there may be several reasons why HIIT may be more effective than SSE, one of the more recent thoughts is that exercise at a higher intensity, such as with HIIT, may suppress appetite to a greater extent than SSE (Deighton, Barry, et al., 2013; Deighton, Karra, et al., 2013). This suppression of appetite is due to increasing the release of appetite suppressing hormones and inhibiting the release of appetite stimulating hormones, which could lead to less energy intake and therefore weight loss over a period of time (Boutcher, 2011; Gibala & McGee, 2008; Hottenrott et al., 2012; Whyte et al., 2010).

The purpose of this study was to investigate whether there is a greater reduction in appetite following a HIIT exercise session compared to an SSE exercise session.

4.2. Methods

4.2.1. Participants

Six healthy males, age, 20.2 ± 0.75 years; height, 181.1 ± 9.4 cm; weight, 81.2 ± 1.7 kg; body fat percentage, 7.9 ± 1.6%, participated in this study. Subjects were non-smokers, had maintained a stable weight for six months prior to the study, and were not on any type of calorie-restricted diet. The subjects also engaged in regular aerobic exercise for at least six month prior to the study. To meet this criteria, subjects performed at least 150 minutes of moderate-intensity exercise per week, which could be achieved by 30-60 minutes of moderate intensity exercise five days per week or 20-60 minutes vigorous exercise three times per week (Garber et al., 2007).

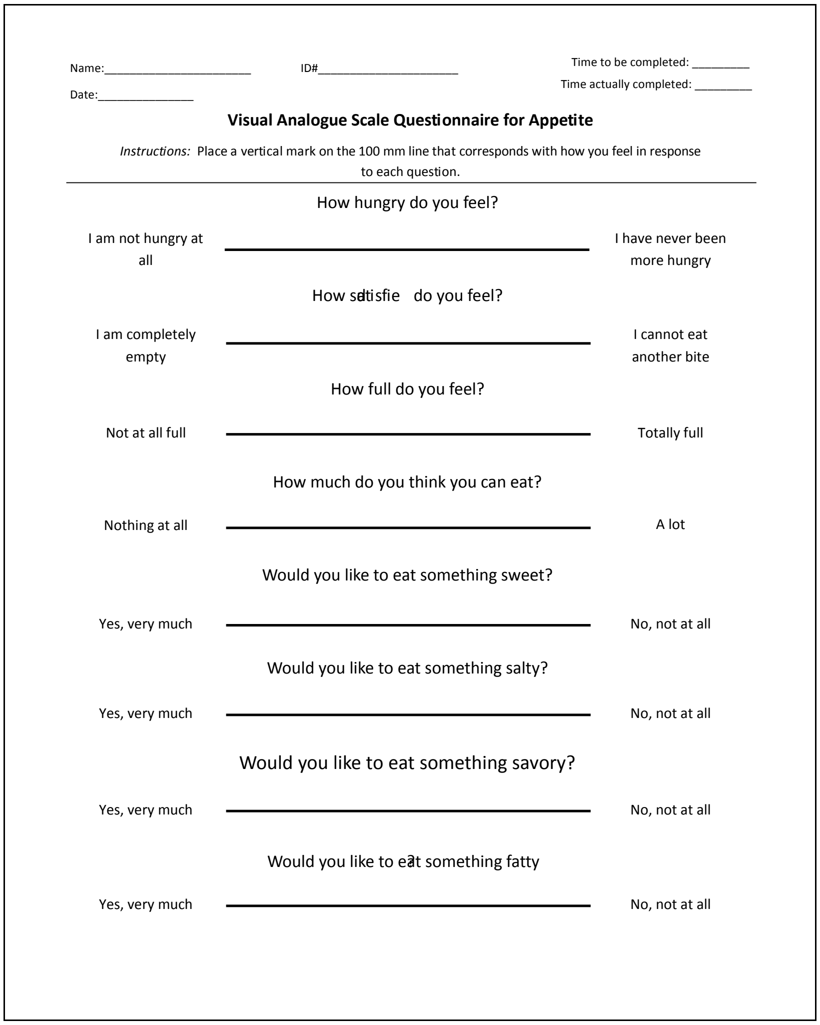
4.2.2. Participant Screening

The study was approved by the university's Institutional Review Board. Prior to the main trial, participants met with investigators to sign informed consent and fill out the Physical Activity Readiness Questionnaire (PAR-Q) and the Global Physical Activity Questionnaire (GPAQ) questionnaire to evaluate their current health and activity level. At this time, participants were informed of testing protocols and other basic information, such as age, was also collected.

4.2.3. Experimental Protocol

Participants performed 3 experimental protocols (control, SSE, and HIIT), each separated by four days in a counterbalanced Latin square design. All trials were identical except for the 40 minutes that either exercise (SSE and HIIT) or rest (control) was performed. In the first trial, height, weight and skinfold measurements were taken during the 30 minutes between the first appetite survey and the second appetite survey. To determine the heart rate for the main trials, the formula of 220-age was used to predict maximum heart rate (HRM), and then a percentage of the HRM was used to determine intensity for exercise.

Participants completed a food log that included everything they consumed for the 24 hours prior to the first trial, and this food log was replicated as closely as possible for the 24 hours prior to each remaining trial. Participants were instructed to abstain from strenuous physical activity and alcohol for 48 hours prior to each trial. Participants arrived to the laboratory in the morning at their instructed times after an overnight fast of at least 12 hours. During each trial, appetite perceptions were assessed at baseline, 30 minutes into the trial, immediately following exercise, and then every 30 minutes for 4 hours following the completion of exercise using a visual analogue scale (VAS) 100mm in length with word descriptors anchored at each end (Flint et al., 2000) (Figure 1). Subjects consumed one cup of 1% low fat chocolate milk immediately following the first VAS, and one more cup of 1% low fat chocolate milk immediately following the completion of exercise (or rest in the control trial). Heart rate monitors were worn during the HIIT and SSE trial to ensure that participants were performing exercise at the defined intensity.


Name:______________________ ID#_____________________ Time to be completed: _________

Time actually completed: _________

Date:_______________

Visual Analogue Scale Questionnaire for Appetite

Instructions: Place a vertical mark on the 100 mm line that corresponds with how you feel in response to each question.

How hungry do you feel?

I am not hungry at all ______ I have never been more hungry

How satisfied do you feel?

I am completely empty ______ I cannot eat another bite

How full do you feel?

Not at all full ______ Totally full

How much do you think you can eat?

Nothing at all ______ A lot

Would you like to eat something sweet?

Yes, very much ______ No, not at all

Would you like to eat something salty?

Yes, very much ______ No, not at all

Would you like to eat something savory?

Yes, very much ______ No, not at all

Would you like to eat something fatty?

Yes, very much ______ No, not at all

Figure 1. VAS survey to measure perceived appetite

4.2.4. HIIT Session

The HIIT trial consisted of a five minute warm up jogging at a comfortable pace, followed by 10 two-minute intervals running at 90-95% of HRM. Each interval was separated by one minute of rest. The HIIT trial concluded with a five minute cool down walking at a comfortable pace.

4.2.5. SSE Session

The SSE trial consisted of a five minute warm up jogging at a comfortable pace, then 30 minutes jogging at 68-72% of HRM. The SSE trial also concluded with a five minute cool down walking at a comfortable pace.

4.2.6. Control Session

The control trial consisted of 40 minutes of rest.

4.2.7. Statistical Analysis

A repeated measures ANOVA was used to assess differences in appetite scores between trials and time points. When significance was found at a specific time point, a Tukey pairwise comparison was used to determine which trials were significantly different. Significance was accepted as $p < 0.05$.

4.3. Results

When food logs between trials were compared for each subject, it was found they had eaten similar foods and amounts prior to each trial. To score responses on the VAS, the point that the subject marked on the 100 mm line in response to each question was measured from the left end point of the line. This measurement in mm was recorded as their score for each question. The scores for questions two and three were inverted because these questions were opposite the rest of the questions in relation to appetite. There were a few key findings from the data. For questions one, two, and three on the VAS, a significant difference was found at minute 70, which was immediately taken after exercise (or rest) in the trials. For all three questions, the VAS scores for HIIT were significantly lower than the control trial at minute 70 (refer to Table

1, 2, and 3). There was no significance found for question four (refer to Table 4).There was no other significance found for the last four questions dealing with taste preference (refer to Table 5, 6, 7, and 8).

Table 1. *VAS scores (mm) for question 1 "How hungry do you feel?"*

Minute	Control	HIIT	SSE
0	51.7±14.3	40.3±28.0	52.7±16.4
30	51.3±15.5	58.8±17.9	42.3±12.9
70	55.7±17.5	34.5±13.5*	52.3±9.9
100	56.0±21.8	43.2±16.6	48.5±22.7
130	47.6±20.2	48.5±15.5	53.2±25.6
160	52.2±23.3	52.8±15.4	63.3±15.3
190	54.2±22.6	60.5±19.3	72.7±17.3
220	57.0±20.8	61.8±19.6	74.8±15.4
250	53.4±21.7	57.8±23.8	65.8±31.0
280	57.4±24.3	63.7±24.7	64.3±26.1
310	64.6±27.4	62.5±24.1	72.2±21.1

Note: Values are means ± SD
*p = 0.0476 for HIIT vs. control

Table 2. *VAS scores (mm) for question 2 "How satisfied do you feel?"*

Minute	Control	HIIT	SSE
0	67.2±9.4	52.0±19.6	57.0±21.1
30	62.2±10.7	65.0±18.7	57.0±12.5
70	67.8±11.5	45.2±10.3*	57.8±13.2
100	71.6±10.7	57.0±10.4	60.3±13.2
130	68.0±13.5	59.5±8.5	67.7±12.5
160	71.4±10.8	67.2±8.4	76.3±10.4
190	75.0±13.3	70.8±13.3	78.8±13.2
220	71.8±10.1	73.7±8.1	77.5±13.8
250	71.0±7.4	74.2±13.1	82.2±12.5
280	76.9±9.8	77.3±6.2	72.8±16.5
310	79.2±10.3	82.2±7.1	76.0±15.6

Note: Values are means ± SD
*p = 0.0116 for HIIT vs. control

Table 3. *VAS scores (mm) for question 3 "How full do you feel?"*

Minute	Control	HIIT	SSE
0	69.0±11.6	62.7±21.4	66.2±15.8
30	60.5±16.2	66.7±19.2	53.5±15.9
70	67.2±11.0	44.7±12.6*	58.5±14.9
100	72.2±10.3	52.8±14.3	65.5±8.5
130	69.2±14.6	61.2±8.7	69.5±9.4
160	72.0±13.7	67.2±9.2	76.3±12.5
190	75.2±11.9	72.7±12.6	79.7±12.4
220	74.8±8.5	76.7±6.1	81.7±14.7
250	72.8±11.7	77.2±8.8	79.3±13.8
280	81.4±8.1	76.8±7.2	76.3±14.0
310	85.4±7.2	80.5±6.9	78.8±13.8

Note: Values are means ± SD

*$p = 0.0225$ for HIIT vs. control

Table 4. *VAS scores (mm) for question 4 "How much do you think you can eat?"*

Minute	Control	HIIT	SSE
0	62.3±16.7	57.5±15.2	54.2±14.9
30	59.0±17.4	65.0±9.7	53.2±8.5
70	61.8±16.3	46.7±12.8	60.8±16.0
100	59.2±18.3	50.2±12.3	63.3±8.3
130	43.8±18.6	56.7±7.7	67.3±5.0
160	67.4±15.5	67.2±6.0	70.5±6.2
190	68.2±14.7	67.3±7.0	77.2±6.9
220	69.6±12.8	70.8±8.7	77.8±11.0
250	70.8±15.9	68.2±5.7	80.3±8.8
280	78.4±10.3	69.2±7.4	71.2±15.3
310	79.4±11.4	73.5±4.5	78.3±13.0

Note: Values are means ± SD

Table 5. *VAS scores (mm) for question 5 "Would you like to eat something sweet?"*

Minute	Control	HIIT	SSE
0	49.0±21.0	62.5±21.9	64.2±25.3
30	50.5±20.8	63.0±19.9	66.2±13.1
70	52.8±25.0	61.8±22.4	61.7±27.6
100	47.6±20.4	61.3±21.6	69.7±20.8
130	45.6±19.7	55.7±25.1	65.0±22.9
160	48.2±16.6	56.7±27.0	61.2±20.7
190	45.6±20.9	54.0±29.0	56.2±17.4
220	50.0±19.8	57.8±26.2	54.0±19.9
250	44.0±23.5	53.7±24.3	61.7±19.6
280	48.8±18.1	51.7±25.1	56.0±22.8
310	44.0±19.5	49.3±23.7	60.5±24.7

Note: Values are means ± SD

Table 6. *VAS scores (mm) for question 6 "Would you like to eat something salty?"*

Minute	Control	HIIT	SSE
0	53.2±24.8	61.7±29.4	56.5±24.1
30	54.2±30.6	60.7±23.9	62.2±19.2
70	55.0±31.8	66.0±24.6	67.5±21.7
100	63.2±26.4	59.5±30.7	71.5±22.8
130	59.4±29.4	59.2±27.6	62.5±27.1
160	58.0±28.6	55.7±29.1	55.0±25.5
190	46.2±28.3	48.5±31.7	50.8±22.0
220	46.0±27.2	47.8±29.3	51.0±25.3
250	41.4±28.7	48.7±31.0	52.8±30.1
280	39.6±25.6	50.5±32.5	43.5±27.4
310	40.4±24.6	43.0±27.4	47.8±27.9

Note: Values are means ± SD

Table 7. *VAS scores (mm) for question 7 "Would you like to eat something savory?"*

Minute	Control	HIIT	SSE
0	36.8±24.6	43.7±22.0	34.5±11.8
30	37.3±18.3	47.7±23.2	39.0±15.9
70	29.7±19.5	60.2±28.5	41.8±11.8
100	36.0±18.0	55.8±28.1	41.0±15.8
130	31.2±19.6	51.3±28.4	44.7±23.3
160	33.4±14.5	47.2±30.0	28.2±15.6
190	26.2±13.9	40.5±27.7	26.0±17.4
220	28.2±16.3	41.8±27.5	23.8±20.6
250	30.2±24.0	40.7±28.6	25.2±22.2
280	22.6±12.6	40.7±21.5	30.2±26.2
310	24.6±14.3	32.8±13.3	29.2±23.1

Note: Values are means ± SD

Table 8. *VAS scores (mm) for question 8 "Would you like to eat something fatty?"*

Minute	Control	HIIT	SSE
0	58.2±26.9	65.7±20.2	61.2±8.1
30	58.3±32.4	63.0±28.1	60.8±18.2
70	55.3±31.0	76.5±21.2	68.0±21.7
100	64.2±25.3	65.7±32.5	61.0±21.1
130	64.2±26.8	63.7±28.6	59.5±27.7
160	64.6±19.5	62.2±32.5	48.2±29.4
190	58.0±23.2	54.2±33.3	45.5±28.8
220	54.2±18.9	56.0±32.7	41.8±23.3
250	54.2±25.6	58.7±33.0	42.0±25.2
280	48.4±17.9	57.7±33.1	44.8±28.5
310	47.6±20.9	48.8±27.2	47.2±33.1

Note: Values are means ± SD

4.4. Discussion

The purpose of this study was to investigate whether there is a greater reduction in appetite following a HIIT exercise session compared to an SSE exercise session. It was found that there was a significantly greater reduction in perceived appetite immediately following the

HIIT trial compared to the control trial in terms of three of the four questions regarding appetite on the VAS. The results from this study were comparable to previous research. Deighton, Karra et al. (2013) found that appetite was significantly reduced during and upon completion of exercise to a greater extent in their HIIT trial when compared to control, but no significant differences from hour 3.5 on. Deighton et al. (2012) also found suppressed appetite immediately upon completion of the sprint interval trial compared to the control and traditional exercise (SSE) trial. However Deighton et al. (2012) found that appetite was more elevated later in the trial when compared to the traditional exercise trial, which was not seen in this study. Although not significantly different, perceived appetite in the HIIT trial was also less than the SSE trial immediately following exercise. However, this reduction in appetite in the HIIT trial only lasted an hour to an hour and a half following exercise, then returned to similar levels with the other two trials. The current study is similar to other research that compared appetite responses between exercise and control trials. It was found that appetite scores were lower immediately and for about an hour following exercise trials compared to control trials (Broom et al., 2007; Vatansever-Ozen et al., 2011).

When it came to taste preference (the last four questions on the VAS), no significant differences were found. However, there were non-significant lower scores when it came to preference for sweet foods following SSE and higher scores when it came to preference for savory foods following HIIT. There were also higher scores when it came to preference for fatty foods immediately following exercise in the HIIT trial, but this leveled out with SSE trial scores within a half hour after exercise. Scores were very similar between all three trials when it came to preference for salty foods. To the knowledge of the investigators in this study, there is very little or no previous research on taste preferences following exercise of different intensities to compare with results from this study.

The results from this study contradict with those of another study that found no differences in appetite when comparing a trial of five days of exercise to a trial of five days control with no exercise (Ebrahimi, Rahmani-Nia, Damirchi, Mirzaie, & Pur, 2013). However, in this study both males and females were used, which could have had an effect on results.

One strength of this study was that the experimental protocol was a repeated measures. This strengthens data since each participant performs each trial and is used as their own control. One major limitation of this study is the small sample size used. The goal was to have 15 subjects. After speaking to several upper level Health, Nutrition, & Exercise Science classes as well as several lower level Health, Nutrition, & Exercise Science classes at NDSU, there were 26 individuals that signed up to potentially participate. After contacting them all by email as well as by telephone, only 10 responded stating they would attend an informational meeting. However, only nine actually attended. After being informed of what the study consisted of, one declined to participate, one was unable to participate due to injury, and another failed to show up to trials, leaving only six subjects who completed the study. Another problem encountered was that one of the six subjects didn’t fill out all of the appetite surveys for one of their trials, so most of the stats contain only the data from the five subjects with complete surveys for each trial. Significance may have been identified if there was a larger sample size. However, since the sample size was so small, small changes in appetite scores or data were not considered significant.

One way this study could be improved would be to include more subjects. It would also have been beneficial to more tightly control each trial after exercise was performed. The subjects were free to go after finishing the exercise or rest portion of their trial and filling out the third VAS. If we were able to keep the subjects under our supervision for the remaining four hours of the trial, we would have been able to monitor and make sure that subjects didn't eat anything until all VAS' were filled out.

4.5. Conclusion and Application

In conclusion, it was found that HIIT caused a reduction in appetite immediately following exercise. However, this reduction in appetite was only significantly different immediately following exercise, then returned to similar scores as the other two trials. This strengthens previous research that exercise of a HIIT nature may result in appetite suppression immediately following exercise. Although this suppression of appetite only occurred for a short time after exercise, this may lead to less energy intake, which could partly explain why there have been greater reductions in weight following HIIT programs.

Although there seemed to be patterns for different preferences of food following each trial, there was no significance found. More research in this area of taste preferences following exercise at different intensities could be beneficial in determining which types of exercise lead to less preferences for unhealthier types of food.

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CHAPTER 5. DISCUSSION

The purpose of this study was to investigate whether there is a greater reduction in appetite following a HIIT exercise session compared to an SSE exercise session. The questions to be answered from this research were 1) What are post exercise appetite responses to two different intensities of exercise? 2) Does HIIT lead to a greater suppression of appetite than SSE following exercise? And 3) Is there a preference for types of food (sweet, salty, savory, fatty) to be ingested following exercise of different intensities? After performing this study, all of these research questions were answered to at least some extent. It was found that there are differences in appetite responses following exercise of different intensities. Although the only significance found was that HIIT produced a greater suppression of appetite immediately after exercise compared to the control trial, there were patterns that showed that HIIT does produce a greater suppression of appetite compared to SSE as well. Patterns in preference for different categories of food following exercise of different intensities were also found. There was more preference for sweet foods following both SSE and HIIT, a greater preference for savory food following HIIT, and less preference for fatty foods following SSE. These results were not significant, however.

The biggest improvement that could be made to this study would be to include more subjects. Fifteen subjects would have been preferable, but after individuals not responding, injuries (prior to the study), and drop outs after being informed of what the study consisted of, this study ended up including only 6 people. However, a repeated measures design was used so each subject performed each trial and was used as their own control, which is a strength of this study.

The results found from this study support previous research and strengthen the idea that exercise of a HIIT nature has the potential to cause suppression of appetite following exercise, which could possible lead to reduced energy intake. Although this is not the only factor, the results from this study help support a suppression of appetite as one of the possible reasons that HIIT programs may cause greater weight loss than more traditional SSE exercise programs.

The findings from this study were consistent with previous research. However, future research should focus on the preference for different types of foods (questions 5-8 on VAS) since there currently isn't much research in that area. This could be useful in determining which type of exercise results in preferences for unhealthier foods, which could possibly add more explanation as to why certain exercise protocols are more successful in terms of weight loss than others.

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APPENDIX A. IRB APPROVAL

NDSU NORTH DAKOTA STATE UNIVERSITY

April 7, 2015

Dr. Donna Terbizan
Department of Health, Nutrition & Exercise Sciences
BBFH 1D

IRB Approval of Protocol #HE15216, "The Effects of Exercise Intensity on Perceived Post-Exercise Appetite"
Co-investigator(s) and research team: Megan Groen

Approval period: 4/7/15 to 4/6/16
Continuing Review Report Due: 3/1/16

Research site(s): NDSU Funding Agency: n/a
Review Type: Expedited category # 4
IRB approval is based on the original submission, with revised: protocol and consent form (received 4/7/15).

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

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

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

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

Sincerely,

Kristy Shirley

Kristy Shirley, CIP, Research Compliance Administrator

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

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

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

NDSU is an EO/AA university.

APPENDIX B. GPAQ

Global Physical Activity Questionnaire (GPAQ)

WHO STEPwise approach to NCD risk factor surveillance

Surveillance and Population-Based Prevention
Prevention of Noncommunicable Diseases Department
World Health Organization
20 Avenue Appia, 1211 Geneva 27, Switzerland
For further information: www.who.int/chp/steps

GPAQ

Physical Activity			
Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person. Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. [Insert other examples if needed]. In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.			
Questions		Response	Code
Activity at work			
1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like [carrying or lifting heavy loads, digging or construction work] for at least 10 minutes continuously? [INSERT EXAMPLES] (USE SHOWCARD)	Yes 1 No 2 If No, go to P 4	P1
2	In a typical week, on how many days do you do vigorous intensity activities as part of your work?	Number of days └─┘	P2
3	How much time do you spend doing vigorous-intensity activities at work on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P3 (a-b)
4	Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking [or carrying light loads] for at least 10 minutes continuously? [INSERT EXAMPLES] (USE SHOWCARD)	Yes 1 No 2 If No, go to P 7	P4
5	In a typical week, on how many days do you do moderate intensity activities as part of your work?	Number of days └─┘	P5
6	How much time do you spend doing moderate-intensity activities at work on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P6 (a-b)
Travel to and from places			
The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship. [insert other examples if needed]			
7	Do you walk or use a bicycle (pedal cycle) for at least 10 minutes continuously to get to and from places?	Yes 1 No 2 If No, go to P 10	P7
8	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days └─┘	P8
9	How much time do you spend walking or bicycling for travel on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P9 (a-b)
Recreational activities			

The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (leisure), [insert relevant terms].			
10	Do you do any vigorous-intensity sports, fitness or recreational (leisure) activities that cause large increases in breathing or heart rate like [running or football,] for at least 10 minutes continuously? [INSERT EXAMPLES] (USE SHOWCARD)	Yes 1 No 2 If No, go to P 13	P10
11	In a typical week, on how many days do you do vigorous intensity sports, fitness or recreational (leisure) activities?	Number of days └─┘	P11
12	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P12 (a-b)

Continued on next page

GPAQ, Continued

Physical Activity (recreational activities) contd.			
Questions		Response	Code
13	Do you do any moderate-intensity sports, fitness or recreational (leisure) activities that causes a small increase in breathing or heart rate such as brisk walking,(cycling, swimming, volleyball)for at least 10 minutes continuously? [INSERT EXAMPLES] (USE SHOWCARD)	Yes 1 No 2 If No, go to P16	P13
14	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational (leisure) activities?	Number of days └─┘	P14
15	How much time do you spend doing moderate-intensity sports, fitness or recreational (leisure) activities on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P15 (a-b)
Sedentary behaviour			
The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. [INSERT EXAMPLES] (USE SHOWCARD)			
16	How much time do you usually spend sitting or reclining on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs mins	P16 (a-b)

APPENDIX C. PAR-Q FORM

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____ DATE ____________________

SIGNATURE OF PARENT ________________________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

APPENDIX D. FOOD LOG

Name:_________________ID#_______________Date:__________

24 hour food record or one day from the time you get up to when you go to bed.

Time	How much (specify units—cups, tablespoons, fl oz, wt in oz NOT g)	Food item	Any additional information?

APPENDIX E. VAS SURVEY

Name:________________________ ID#_______________________ Time to be completed: _________

Time actually completed: _________

Date:________________

Visual Analogue Scale Questionnaire for Appetite

Instructions: Place a vertical mark on the 100 mm line that corresponds with how you feel in response to each question.

Left anchor	Question	Right anchor
I am not hungry at all	How hungry do you feel?	I have never been more hungry
I am completely empty	How satisfied do you feel?	I cannot eat another bite
Not at all full	How full do you feel?	Totally full
Nothing at all	How much do you think you can eat?	A lot
Yes, very much	Would you like to eat something sweet?	No, not at all
Yes, very much	Would you like to eat something salty?	No, not at all
Yes, very much	Would you like to eat something savory?	No, not at all
Yes, very much	Would you like to eat something fatty?	No, not at all

(Flint et al., 2000)