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ATTENTIONAL BIAS, INHIBITORY CONTROL, AND FOOD REINFORCEMENT AS MECHANISMS PROMOTING EATING BEHAVIOR AFTER EXERCISE

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ATTENTIONAL BIAS, INHIBITORY CONTROL, AND REINFORCEMENT AS MECHANISMS PROMOTING EATING BEHAVIOR AFTER EXERCISE

THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the College of Agriculture, Food and Environment at the University of Kentucky

By

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2022

ABSTRACT OF THESIS

ATTENTIONAL BIAS, INHIBITORY CONTROL, AND FOOD REINFORCEMENT AS MECHANISMS PROMOTING EATING BEHAVIOR AFTER EXERCISE

Background: Excess weight and obesity are serious health conditions characterized by modifiable and nonmodifiable risk factors. Exercise is a common method for achieving weight loss; however, results are not always achieved due to post compensatory behaviors. Increased energy intake (EI) is thought to be the main compensatory behavior hindering weight loss among overweight and obese adults. It is important to determine and understand the mechanisms behind energy compensation following exercise, as this will allow for the discovery of future interventions that may provide individuals with ways to improve exercise as a weight loss treatment. Objective: To determine if a single dose of aerobic exercise will alter behavioral constructs known to promote energy intake. Methods: Thirty sedentary overweight to obese (BMI 25 kg/m2 and above) participants aged 18-35 years enrolled in a two-visit counterbalanced crossover design trial. The effects of ana cute bout of aerobic exercise and sedentary activity of food reinforcement, attentional bias, and inhibitory control for food cues was assessed. Results: Attentional bias for food cues increased following the acute bout of exercise while remaining stable after the acute bout of sedentary activity, independent of hunger. Exercise did not influence food reinforcement or inhibitory control for food cues. Conclusions: An acute bout of exercise increased attentional bias toward food cues compared to sedentary activity, pointing to its potential role as a compensatory mechanism responsible for minimizing weight loss in sedentary adults classified as overweight or obese. More prolonged trials are needed to assess the effect attentional bias has during a longer exercise intervention.

KEYWORDS: compensatory behavior(s), behavioral mechanisms, attentional bias, inhibitory control, food reinforcement

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May 6, 2022

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Chapter One: Introduction

Background

Individuals considered overweight or obese are classified based on their body mass index (BMI). A BMI of 25.0 to 29.9 falls into the overweight range and a BMI of 30.0 or greater falls into the obese range (1). Excess weight and obesity are accompanied by both modifiable and non-modifiable risk factors. Modifiable risks would include consuming energy-dense foods, lack of physical activity, and other unhealthy lifestyle practices that create a positive energy balance. Non-modifiable risks would include age, gender, family history, and genetics (2). Carrying excess weight can increase a person's risk for more serious health problems like heart disease, diabetes, hypertension, and some cancers (2). Exercise is a common activity that people utilize to lose weight; however, most do not see the desired weight loss due to post-exercise compensatory behaviors that resist the energy deficit required for weight loss (3). Increased energy intake (EI) is thought to be the main compensatory behavior but the exact mechanisms behind this behavior are still being debated. Some have credited it to hedonic processes where individuals classified as overweight to obese have a strong desire or urge to eat due to preferences or the reinforcing value of energy-dense foods (4). Hedonic processes such as taste, pleasure, and reward, are related to the overconsumption of food in the absence of hunger and are often associated with the motivation of satiating those hedonic processes (5). The hedonic-inhibitory model of obesity proposes overconsumption of palatable foods is the result of inadequate response inhibition over the hedonic, appetitive system (5). It is important to determine and understand the mechanisms behind energy compensation following exercise, as this will allow for the discovery of future interventions that may provide individuals with ways to improve initial weight loss and weight loss maintenance with exercise.

Problem Statement

Obesity is a serious health condition that can increase the risk of diabetes, heart disease, and cancer (2). Individuals classified as overweight to obese who exercise to lose weight often experience inconsistent and inadequate weight loss because food-related behavioral compensation disturbs the negative energy balance required for weight loss.

Research Questions

1.) Does an acute bout of exercise cause food to be more salient in the environment (evoke an attentional bias) among individuals classified as overweight to obese compared to a sedentary behavior?
2.) Does exercise alter inhibitory control towards food cues among sedentary individuals classified as overweight to obese compared to a sedentary behavior?
3.) Does exercise alter food reinforcement among sedentary individuals classified as overweight to obese compared to a sedentary behavior?

Hypothesis

We hypothesize that exercise will increase attentional bias towards food cues and food reinforcement while decreasing inhibitory control towards food cues compared to a sedentary behavior in adults classified as overweight to obese.

Chapter Two: Literature Review

Introduction

Individuals that are considered overweight or obese are classified based on their body mass index (BMI). A BMI of 25.0 to 29.9 falls into the overweight range and a BMI of 30.0 or greater falls into the obese range (1). Excess weight and obesity are characterized by both modifiable and non-modifiable risks. Modifiable risks would include consuming energy dense foods, lack of physical activity, and other unhealthy lifestyle practices that create a positive energy balance. Non-modifiable risks would include age, gender, family history, and genetics (2). Carrying excess weight can increase a person's risk for more serious health problems like heart disease, diabetes, hypertension, and some cancers (2). Exercise is a common activity that people utilize to lose weight; however, most do not see the desired weight loss due to post-exercise compensatory behaviors that resist the energy deficit required for weight loss (3). Increased energy intake (EI) is thought to be the main compensatory behavior but the exact mechanisms behind this behavior are still being debated. Some have credited it to hedonic processes (4). Hedonic processes such as taste, pleasure, and reward, are related to the overconsumption of food in the absence of hunger and are often associated with the motivation of satiating those hedonic processes (5). The hedonic-inhibitory model of obesity proposes overconsumption of palatable foods is the result of inadequate response inhibition over the hedonic, appetitive system (5). It is important to determine and understand the mechanisms behind energy compensation following exercise, as this will allow for the discovery of future interventions that may provide individuals with ways to improve initial weight loss and weight loss maintenance

The purpose of this review is to examine the current methods and procedures being used in studies looking at the relationship between compensatory action following exercise and determine gaps within the literature, allowing for more adaptive studies.

Dual-Energy X-Ray Absorptiometry (DEXA or DXA)

Dual-energy x-ray absorptiometry (DXA or DEXA) measures the attenuation of high and low energy x-rays to determine bone density; however, many researchers will use it to measure the amount of bone, fat, and muscle within a person's body to calculate body composition (6). DEXA scans are often used at baseline and after interventions to determine a change in body composition, most notably, in fat mass (3, 7, 8). The present study (chapter three) only assessed body composition at baseline since it was an acute study.

By measuring changes in fat and lean mass, accumulated energy balance (AEB) from pre and post body composition scans can be calculated. Compensation following exercise may be calculated from energy expended (EE) and AEB. One study estimated that the gain of 1kg of fat mass (FM) was equivalent to 12,000kcal and the gain of 1 kg of fat free mass (FFM) was 1780 kcal, while the loss of 1kg of FM and 1kg of FFM was equivalent to 9417kcal and 884kcal, respectively (9). By quantifying the changes in body fat and FFM into energy equivalents (a negative number is body mass is lost) and adding those values to EE during exercise (a positive number), compensation can be quantified. Positive compensation would indicate that the negative energy balance was smaller than anticipated based on EE following exercise indicative of a compensatory response taking place to resist the negative energy balance. Negative compensation would indicate a larger negative energy balance than anticipated based on exercise EE, which would only be possible if concurrent dietary restriction took place (9).

Actiheart

Actiheart is a small, portable electrocardiogram (ECG) that works as a portable monitoring device (10). Several behavioral studies have used the device to measure energy expenditure both during everyday life and during exercise interventions (10).

The Actiheart or other ECG monitors have been used to measure habitual physical activity and then later determine energy expenditure (EE) during exercise (11, 12). The Actiheart device is usually placed at the base of a person's chest and records data every 15 seconds; the device can also be worn while sleeping, showering, and swimming (11). By measuring the participants' habitual movements prior to intervention, it allows for a comparison for after the intervention.

Actiheart was created in England but there is a similar United States company known as Polar that has been used in several studies as well (13). A study done at the University of Pittsburgh used Polar monitors to record the heart rate (HR) of their female participants at 1-minute intervals throughout the entirety of their exercise bout (14). The polar heart rate monitor is attached to a large elastic strap allowing it to sit at the base of a person's sternum or on the wrist like a watch, both allowing for free range-of-motion (13). However, the polar monitor cannot be worn in water-unlike the Actiheart (11). The present study (chapter three) utilized the Polar brand to estimate EE during exercise.

Accelerometer

Another device often used alongside the Actiheart or polar heart monitor is an accelerometer. An accelerometer measures the acceleration or amount of force being exerted onto an object (15).

One study had participants wear the accelerometers on their non-dominant arm while exercising while another study had participants wear two accelerometers, one on the arm and the other on the thigh; both studies used the accelerometers to measure the amount of time spent in different exercise intensities (3, 16).

Unlike the Actiheart, the accelerometers cannot determine energy expenditure and do not measure body composition like the DXA scan, but they are important for research studies. Accelerometers allow researchers the ability to look at exercise intensity and habitual physical activity without having to supervise it or schedule an appropriate meeting time for all parties.

Gaps in Literature

The largest and most obvious gap in this literature is the assessment of energy compensation among males. The majority of studies utilized female participants only (3, 7, 11, 12, 17, 18, 19). It is important to note the lack of male subjects as females experience hormonal oscillations that can influence eating behaviors, such as increased planning around meals, dietary restraint, and emotional eating (20, 21, 22). Some studies saw an increase in compensatory mechanisms or eating following exercise (3, 7, 18), though one attributed this to an adaptation to an increase in EE (18). Other studies saw little to no compensatory changes following exercise (11, 12) or between exercise and control (19). One study looking specifically at self-administered questionnaires in women aged 17-20 years saw an association between greater BMI and emotional eating (17).

Another major gap is the lack of studies that look into cognitive processes that govern eating behaviors. Some researchers have thought the relationship between compensatory responses and exercise is associated with reward-driven eating, or food reinforcement--which will be looked at further in chapter three (23). One study found that food reinforcement was increased following loss of fat-free mass after 12 weeks of exercise but the level of compensatory responses was not associated with an increase in exercise dose (23). However, other researchers found differing information. One study looked at the compensatory mechanism among overweight sedentary adults in different doses of aerobic exercises (control, moderate, and high). Researchers saw a large increase in compensatory mechanisms in the moderate exercise group and another small increase in the high exercise group, indicating that the more an individual exercises, the more they compensate for that loss of energy, although the specific mechanisms were not uncovered (24).

Conclusion

People that are classified as overweight or obese are likely not losing sufficient weight from exercise because of post-exercise compensatory behaviors. An increase in energy intake following exercise, resists the exercise-induces negative energy balance, therefore, resisting weight loss. Several studies have used similar measurements as the present study (chapter three) have implemented; however, very few assessed the mechanisms causing compensatory eating, such as food reinforcement, attentional bias, and inhibitory control for food cues.

Chapter Three: Attentional Bias, Inhibitory Control, and Food Reinforcement as Mechanisms Promoting Eating Behavior After Exercise

Introduction

Attentional Bias. Attentional bias can be described as a person's tendency to process certain types of stimuli over others. In the case of the present study, attentional bias related to food cues is being examined. Individuals classified as overweight to obese have a greater attentional bias for food cues (25, 26, 27, 28). Continuous activation of reward pathways caused by exposure to high-energy-density food cues may contribute to this link. With continual exposure to high-energy-density food cues, it can be suggested that attentional bias related to food cues is a modifiable risk factor for obesity that needs to be studied further to better understand the effects of attentional bias on weight gain and obesity (20). The present study aims to examine the effects exercise has on the attentional bias towards food cues in adults classified as overweight to obese, and due to its influence on eating behavior and weight status, it may represent a novel compensatory mechanism (20).

Inhibitory Control. Inhibitory control can be described as the ability to inhibit impulse responses caused by stimuli in hopes of achieving a different goal or outcome. An example of this is when someone attempting to lose weight would need to inhibit impulses related to food cues in order to achieve weight loss (25). Inhibitory control has been examined in relation to eating behaviors and weight status, where individuals classified as obese tend to have poor inhibitory control in response to food cues when compared to healthy-weight controls (29). Additionally, food intake and an increase in weight is associated with poor inhibitory control in both normal weight and women classified as overweight to obese (25, 30, 31).

Food Reinforcement. Individuals classified as obese find food more reinforcing than normal-weight individuals (32, 33). As mentioned above, one study believes that compensatory responses following exercise are related to reward-driven eating, or food reinforcement (23). Food reinforcement is the measure of an individual's motivation to eat and is a stronger predictor of food intake than just preference (34), and therefore a strong predictor of body weight (35, 36). Energy deficits caused by restricting food increases food reinforcement (34), indicating that an exercise-induced energy deficit may increase food reinforcement in order to maintain energy balance.

Materials and Methods

Subjects

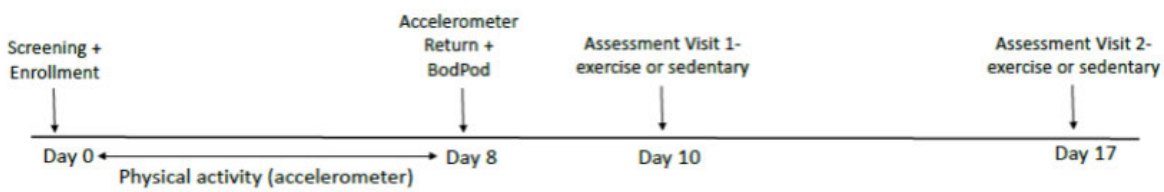
Recruitment for participants occurred in Lexington, KY, and surrounding areas using both print and online media advertising. Print media was distributed around the University of Kentucky campus and Lexington, KY public area, such as grocery stores, local bulletins, and parks. Online media was posted on social media platforms.

Inclusion criteria for this trial included a BMI classification of overweight to obese (25-45 kg/m2), age range of 18-45, not currently participating in any exercise or weight loss activities and had not lost or gained 5% or more of their current body weight in the past year (12 months). Other inclusion criteria included: (1) be free of any cardiac, pulmonary, or metabolic health conditions; (2) able to safely exercise; (3) not taking any medications or dietary supplements that may influence energy expenditure or intake; (4) have not been diagnosed with an eating disorder, clinical depression, or an anxiety disorder. Additionally, female participants had to be premenopausal and not pregnant or lactating. Participants were assessed for basic inclusion criteria and, if deemed initially eligible, were invited to an in-person preliminary screening visit.

Protocol and Design

The University of Kentucky Institutional Review Board (IRB #52127) approved this study on March 25, 2021. This study is a counterbalanced crossover design trial that includes a 2-armed, 2-visit comparison of the acute effects of a single bout of exercise and a single bout of sedentary activity. The two sessions were scheduled one week apart when possible. Pre and post activity measurements included food reinforcement, attentional bias, and inhibitory control for food-related stimuli, detailed below. The research trial was conducted at the University of Kentucky in the Performance Nutrition and Body Composition Laboratory (PNBCL).Timeline of Study is depicted in Figure 1. Tes

Figure 1: Study Flow



Testing

Visit One. Participants met with the study coordinator for a 30-minute orientation, where the study was explained to them, in detail. If eligible and interested, participants signed the informed consent. Participants completed a health history questionnaire and a physical activity readiness questionnaire for everyone form (PAR-Q+). The PAR-Q+ was introduced by Drs. Darren Warburton, Norman Gledhill, Veronica Jamnik, and Shannon Bredin at the 3rd International Congress on Physical Activity and Public Health on May 5-8, 2010 in Toronto, Ontario, Canada and is continually updated (37). An Accu-chek blood glucose test was done to ensure that participants did not have undiagnosed diabetes. Body composition was assessed using air displacement through a BodPod located in the PNBCL. At the end of the visit, participants were given an ActiGraph accelerometer (Pensacola, Florida) that they were told to wear on their wrist or waist for 7 full days to assess their usual physical activity.

Visit Two and Three. Participants were instructed on how to record their daily food intake prior to visit 2. Participants were asked to record the specific foods, quantities, and times they ate so they could repeat them as closely as possible for the third visit. This is to ensure that the intervention environments were as similar as we could make them. The second and third visits were scheduled at the same time, about a week apart on the same weekday and at the same time of day, again, to establish the most similar environment possible. Upon arrival, three to four hours after their last meal, participants completed assessments that measured their food reinforcement, attentional bias, and inhibitory control to food cues once prior to exercise or sedentary activity and then again following exercise or sedentary activity. Visual analog scales (VAS) were used to measure hunger before each assessment. The visits were counterbalanced, that is, we alternated which participant did the exercise or sedentary visit first based on the order they enrolled, this resulted in half of our sample completing the sedentary visit first and half completing the exercise visit first.

Acute Bout of Exercise. Food reinforcement, attentional bias, and inhibitory control for food cues were assessed both before and after an acute bout of exercise. Participants wore a Polar A-300 heart rate monitor with smart-cal™ technology, set to their specific sex, age, weight, activity level, and heart rate. This was used to estimate the participants' energy expenditure, measured in kilocalories (kcal), throughout the exercise session. The exercise sessions were performed on an elliptical ergometer (Octane Fitness ZR8) under laboratory supervision for as long as it took each participant to expend 500 kcal. Exercise intensity was within heart rate (HR) zone 1 or greater. This specific energy expenditure limit was chosen based on the fact that if used for a longterm program, weight loss would be produced (38). Assessments for food reinforcement, attentional bias, and inhibitory control for food cues were performed after a 15-minute rest period following exercise, to allow for participants' heart rate and body to relax, using 3 different computer simulations. Water was allowed for participants but limited to 0.5 L during and after exercise.

Acute Bout of Sedentary Behavior. Similar to the acute exercise bout, food reinforcement, attentional bias, and inhibitory control were assessed before and after sedentary activity. Participants watched a TV program of their choice without commercials, Netflix, for 60 minutes. 0.5 L of water was provided.

Assessments

Hunger. Hunger was assessed via a visual analog scale (VAS) with a rating from 1 (not hungry at all) to 100 (extremely hungry) pre and post exercise and sedentary behavior.

Physical Activity. Actigraph is now considered the "gold standard" when it comes to measuring physical activity and is used most often in clinical trials (39). The GT3X+ accelerometer was used to measure habitual, free-living physical activity to set a baseline prior to the exercise and sedentary activities by measuring raw acceleration, MET rates, and recording the amount of time spent in different intensities of physical activity. If participants meet the guidelines for vigorous physical activity (95 minutes per week), they were excluded from the trial as this indicated they did not meet the eligibility requirements for being sedentary. No participants were excluded based on this criteria.

Food Reinforcement. The Becker-deGroot-Marschak Auction Task (BDM) is an auction-like computer simulation that measures a person's willingness to pay (WTP) for specific food items. Participants are given a set amount of money (e.g. $5) and then shown pictures of food and are told to bid against the computer to win the food. After completing the task, one of the choices was selected at random and the participant was informed if they won or lost. If they won, the participant was given the physical food item and had to pay the amount of their bid, which was taken out of their remuneration. If they lost, they did not get the food item and kept their entire remuneration. In this scenario, the participant is bidding on what they feel is the true value of that food item. The more they bid, the more they value/want the food, which is a validated measure of food reinforcement (40). The average bid amount (across 25 foods) was used as the measure of food reinforcement.

Attentional Bias. The visual probe procedure was used to measure attentional bias for food cues. Eye-tracking software measured how long a participants' eyes fixated on images on the screen in milliseconds (ms). Twenty food-related images (energy dense foods) matched with twenty non-food-related images (neutral) appeared on the computer screen, side by side, one pair at a time for 3,000ms (3 seconds). The twenty image pairs were presented twice with the orientation (food cue on right vs on left) switched and order randomized. There were also twenty pairs of neutral only images (control) included. After 3,000ms, a visual probe appeared on one side of the screen in place of the images. Participants were instructed to indicate which side the probe appeared on by pressing the corresponding computer key. The amount of time spent looking at each image was measured in ms and the percentage of time looking at the food images was averaged across all trials and used as the measurement for attentional bias towards food cues (percent fixation time) (41).

Inhibitory Control. A Go/No-Go task simulation was used to measure participants' inhibitory control for food cues by responding to images of food and non-food (neutral) items. Similar to the attentional bias task, food related images were highly appetizing, energy dense foods while neutral images were non-food objects. Participants were shown a specific image followed by a solid green or blue square. When the square turned green the participants were instructed to respond by pressing a previously indicated keyboard button, such as the spacebar, indicating go; when the square turned blue, participants were instructed to not press any buttons, indicating no-go. If a participant responded to the blue square following a food-related image, this indicated poor inhibitory control associated with food (they were unable to inhibit responding when presented a food cue) (42). Percentage of inhibitory fails (failed to inhibit responding) when a food cue was presented was used as the main outcome measure of inhibitory control for food cues. The true nature and purpose of these tasks were kept from the participants to allow for proper blinding but were disclosed to them at the end of the trial.

Statistical Analyses

SPSS version 28 (IBM Corp.) was used for all statistical analyses. Binary explanatory variables were quantitative and categorical: a bout of exercise vs bout of sedentary activity, before exercise vs after exercise, male vs female. Independent sample T tests tested for differences in demographics, duration and intensity for the exercise bout between men and women. Analysis of variance (ANOVA) models evaluated the relationships between condition and time for attentional bias and inhibitory control. Mediation analyses were used to assess the interference between inhibitory control on exercise and attentional bias as well as the effect of inhibitory control on time and attentional bias under the condition of exercise. Hunger scores were used as a covariate in the ANOVA models and as a predictor in regression models to determine if hunger influenced attentional bias, inhibitory control, or food reinforcement. Based on a previous study (43) we determined that for this present study, with a power of 0.80 and an alpha of 0.05, and sample size of at least n=30 would be needed to find an effect size of 0.53 or larger.

Chapter Four: Results

Results

Baseline mean age and BMI were 32.9 and 32.7, respectively. Anthropometric measurements were not taken post intervention due to the nature of this particular study. A two visit study with a single large dose of exercise would provide little to no change in anthropometric changes in the population. Table 1 shows the demographic and anthropometric values for our participants, indicating there were no differences in age, BMI, or physical activity between males and females. Females did, as expected, have a greater percent body fat than males.

Table 1: Baseline demographic measures of study participants

	Male (n=16)	Female (n=14)	All (n=30)
Age (years)	31.1 ± 6.1	35.0 ± 8.8	32.9 ± 7.6
BMI (kg/m^2)	31.7 ± 4.9	33.7 ± 5.1	32.7 ± 5.2
% body fat*	34.6 ± 6.9	43.3 ± 6.3	38.5 ± 8.0
VPA	2.9 ± 9.4	7.5 ± 17.2	5.1 ± 13.7

Data present as means ± SD
*Significant difference between sex ($P \leq 0.05$)
VPA: vigorous and very vigorous physical activity, 7-day total from accelerometer

Table 2 details the self-selected intensity and time of exercise chosen by the participants on their exercise visit.

Table 2: Time and energy expenditure (Kcal) of the acute bout of exercise among study participants.

	Male (n=16)	Female (n=14)	All (n=30)
Total time (minutes)*	36.7 ± 4.1	53.6 ± 8.2	46.38 ± 5.2
Zone 3-4 time (minutes)	30.1 ± 1.1	34.8 ± 6.79	33.1 ± 3.9
Kcal	506.5 ± 1.5	498.9 ± 14.1	502.4 ± 7.6

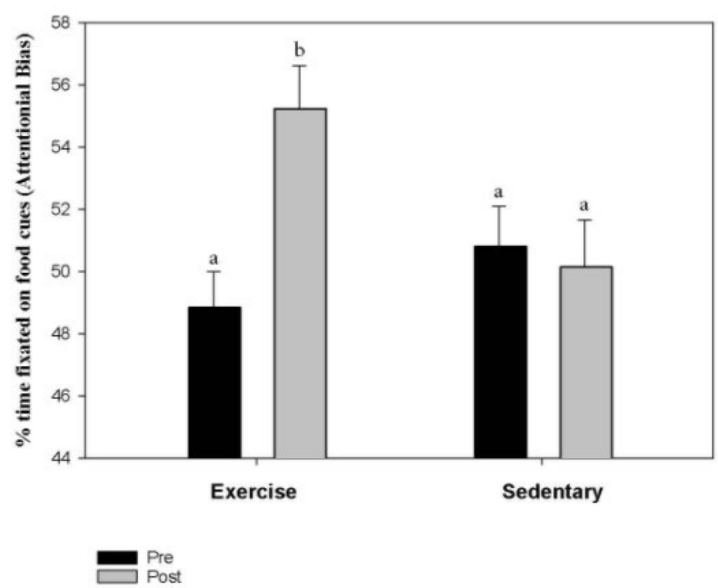
Data present as means ± SE
*Significant difference between sex ($P \leq 0.05$)
Zone 3-4: refers to heart rate reserve zones 3-4 (70-100% of maximal heart rate reserve)

Kcal: Amount of energy (in kcal) expended during the exercise bout (instructed to stop after reaching 500 kcal)

Effects of Exercise and Sedentary Behavior on Attentional Bias

Attentional bias was assessed based on the percentage of time fixated on food cues for both pre and post exercise and sedentary behavior when using a 3,000ms presentation time. The time spent fixated on food cues increased from pre to post during the exercise condition, shown in Figure 2, from 48.85% to 55.24%. The percentage of time for pre-exercise, and pre and post-sedentary are all depicted in Figure 2 with the letter a, because they are all statistically the same. The only different value is post-exercise, depicted with the letter b.

Figure 2: A significant time (pre vs. post) by condition (exercise vs sedentary) interaction was observed for Attentional Bias scores (percentage of time fixated on food cues) (P=0.008). Attentional bias significantly increased pre to post exercise bout where participants expended 500 kcal while no significant changes were observed between pre to post sedentary activity (watching TV for 60 minutes).



The percentage of time fixated on food cues was relatively unchanged in the sedentary conditions, 50.81% pre and 50.15% post (P=0.008). Using a full and reduced linear regression model, BMI proved to be the only independent predictor of attentional bias when other predictors were involved, as shown in Table 3, indicating there were no sex or hunger effects on attentional bias towards food cues.

Table 3: Quantile regression models predicting attentional bias at all-time points among overweight to obese, sedentary participants

Effect	β	SE	P
Full model			
Intercept	66.13	8.21	0.00
Inhibitory Control	0.07	0.09	0.45
BMI	-0.63	0.24	<0.01
Hunger[1]	0.03	0.04	0.44
Sex	3.68	2.53	0.15
Reduced model			
Intercept	75.88	7.67	0.00
BMI	-0.75	0.23	<0.01

[1]Hunger scores were self-reported on a 0-100 scale and were taken prior to each Attentional bias and inhibitory control assessments

Effects of Exercise and Sedentary Behavior on Inhibitory Control

Inhibitory control was measured as the percentage of inhibitory fails, expressed in Table 4. T tests determined that female participants had better inhibitory control when compared to males (p=0.03); however inhibitory control was not changed following exercise or sedentary behavior.

Table 4: No significant condition, time, or condition by time effects for inhibitory control measured as percentage of inhibitory fails to the stop signal following a food cue.

	Pre (n=30)	Post (n=30)	Total (n=60)
Exercise	8.67 ± 2.0	11.73 ± 2.8	10.20 ± 1.72
Sedentary	10.40 ± 2.4	13.87 ± 2.90	12.13 ± 1.9
Total	9.53 ± 1.58	12.80 ± 2.05	

Condition by time effect size (d) = -0.032

Effects of Exercise and Sedentary Behavior on Food Reinforcement

Food reinforcement was not changed following exercise or sedentary behaviors. Table 5 details the mean monetary bid amounts for pre and post exercise and sedentary behavior.

Table 5: No significant condition, time, or condition by time effects for food reinforcement measured as dollar bid amount following food image

	Pre (n=30)	Post (n=30)	Total (n=60)
Exercise	1.78 ± 1.60	1.71 ± 1.60	1.74 ± 1.60
Sedentary	1.84 ± 1.62	1.89 ± 1.65	1.86 ± 1.64
Total	1.81 ± 1.61	1.80 ± 1.63	

Data presented as mean ± SD
Condition by time effect size (d) = 0.000

Mediation analyses did not reveal any significant effects between inhibitory control and attentional bias at any time point or as changes in response to exercise. Therefore, one's impulsiveness did not influence their attentional bias at baseline, after exercise, or in response to exercise.

Chapter Five: Discussion

Discussion

The major finding of our study is that a large dose of acute exercise increases the amount of time spent fixated on food cues in sedentary adults classified as overweight to obese. This is an important finding as attentional bias related to food cues is a modifiable risk factor for obesity (20), and may allow for the discovery of future interventions that may provide individuals with ways to improve initial weight loss and weight loss maintenance with exercise. An important part of assessing attentional bias in this population was the adjustment of time for the visual probe instrument for food cues. We began this study with an image presentation time of 1,000ms for the first five subjects as this is what is typically used in attentional bias studies assessing drug abuse disorders (44). Image presentation time was increased for the next five subjects to 2,000ms, as food image presentation time in these tasks can range from 2,000-5,000ms (45, 46). Finally, we increased presentation time to 3,000ms in the last twenty subjects, where we then saw the most consistent results. Subjects that were presented with images for 1,000ms had a large range of percent fixation time of 1.7-60.9%, and only 6.8 trials were deemed valid in the 10 total trials for those first 5 subjects, indicating that this presentation time may be too short for subjects to process and understand the two images they are looking at. The results from the next 5 subjects that had a presentation time of 2,000ms yielded better results, but much like the original presentation time, standard deviations for the percent fixation time of each assessment were large. The standard deviations for percent fixation time for the first 5 subjects ranged from 0 to 50.1, while the second group of 5 had a standard deviation range of 11.5 to 43.9. The last presentation time of 3,000ms yielded the best results, within a standard deviation range of 14.9 to 21.8, indicating 3,000ms is a fitting presentation time to assess attentional bias for food cues among individuals classified as overweight to obese.

Inhibitory control was assessed using images associated with food cues followed by a stop signal, where percent of inhibitory fails (incorrect responses to food when shown a stop signal) indicated inhibitory control. Since neither exercise nor sedentary activity altered inhibitory control for food cues, it appears either a longer exercise intervention is needed to induce changes in inhibitory control or it is not a prevalent mechanism promoting eating behaviors after exercise.

Food reinforcement was measured using images of food items followed by a visual analog scale with monetary values depicted on the scale ranging from $0 to $5. Participants were instructed to rate each food item with a monetary value they were willing to spend in order to receive that item, and not how much they thought the item cost. Neither exercise or sedentary behavior had an effect on food reinforcement. Reasons for this could be the food images utilized; many participants expressed a dislike for the look of certain foods as well as the inability to identify some items despite using a previously validated picture set (47). In future studies, it is important to find images that are both appealing and easy to identify specific to the study population.

Strengths and Limitations

As a pilot study run in the midst of a global pandemic with a smaller number of facilitators, it can be hard to determine if this is an accurate measurement of the population examined. However, we did see an increase in attentional bias between pre and post exercise.

As expected with human researchers and subjects, problems and limitations were met, especially while navigating University, state, and federal guidelines related to the Covid-19 pandemic. Our participants were flexible and cooperative for the changing conditions required for our study, which we are incredibly grateful for. Face masks were required a majority of the time for both subjects and research facilitators, though it was up to the subject if they wanted to keep theirs on throughout the acute bout of exercise for their own comfort. Some participants chose to remove their face masks while others opted not to, which could have some effect on the difference in subject performance. Outside of the pandemic, more limitations were met when it came to the acute bout of sedentary behavior. Participants were instructed to watch a TV program of their choosing, but were limited to those that were not directly related to food. Participants were unaware they were not allowed to watch food-related programs and all choices were dependent on personal preferences. Some chosen programs did contain conversations or images directly related to food, which could not be accounted for prior to viewing. These circumstances could have potentially impacted the participants performance on attentional bias, inhibitory control, and food reinforcement assessments. Although limitations were met, major strengths were as well. All participants were safely able to exercise until they reached the goal energy expenditure of 500 kcals; however, there were various time lengths. More specifically, female participants tended to exercise longer than males.. A majority of participants were also able to complete the study in the desired two-week timeline. The results of this study also provide validation for our attentional bias for food cues assessment, previously used in substance abuse research and modified for food cues for the present study.

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Publications:

Flack, K. D., Anderson, R. E., 3rd, McFee, K. F., Kryscio, R., & Rush, C. R. (2022). Exercise increases attentional bias towards food cues in individuals classified as overweight to obese. *Physiology & behavior*, *247*, 113711. https://doi.org/10.1016/j.physbeh.2022.113711