4-2018

The Relationship Between Habitual Physical Activity and Food Choices

Safiya E. Beckford
University of Nebraska, safiya.beckford@huskers.unl.edu

THE RELATIONSHIP BETWEEN

HABITUAL PHYSICAL ACTIVITY AND FOOD CHOICES

by

Safiya E. Beckford

A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Nutrition and Health Sciences

Under the Supervision of Professor Karsten Koehler

Lincoln, Nebraska

April, 2018

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Safiya Beckford, M.S.

University of Nebraska, 2018

Advisor: Karsten Koehler

Physical activity (PA) and exercise aid in prevention and treatment of obesity and its comorbidities. Previous research has demonstrated a J-shaped curve between activity level and food intake, but minimal research examines whether PA and exercise affect food choices. As such, the aim of this study was to determine the relationship between habitual PA and exercise with food choices. 174 participants completed an electronic survey involving a series of binary choices among food options (aided by visual food cues) with varying reward values and time points. Participants also completed monetary binary choice questions and an exercise and activity questionnaire, with anthropometric data collected upon completion of the surveys. Participants were classified retrospectively based on habitual PA and exercise levels.

Participants with very high PA levels had a greater preference for delayed consumption of high fat ($p=0.040$) and non-sweet foods ($p=0.049$) as well as for the immediate consumption of sweet foods ($p=0.020$). High PA participants were more likely to choose larger portions for delayed consumption over smaller portions for immediate consumption for high fat ($p=0.008$), non-sweet ($p=0.006$), and sweet ($p=0.04$) foods. Participants with high ($p=0.004$) or very high ($p=0.036$) exercise volumes had a greater

preference for low fat foods for both immediate ($p<0.001$) and delayed ($p=0.002$) consumption, with those in the high exercise group also choosing larger amounts of low fat foods for immediate ($p=0.05$) and delayed ($p=0.006$) consumption. There were no statistically significant differences in delayed discounting for money between PA or exercise group, with money discounting being only weakly correlated with food indifference points.

The results of this study suggest that although moderately correlated, PA and exercise exert differential effects on food choices. Participants with higher PA levels were more likely to choose sweet foods for immediate and delayed consumption, while participants with higher exercise volumes had a greater liking and preference for low fat foods. The results also suggest that food choices are more sensitive to differences in physical activity and exercise levels when compared to choices about money.

Table of Contents

List of Multimedia Objects

CHAPTER 1. INTRODUCTION

According to the World Health Organization (WHO) (2016), obesity rates have doubled globally since 1980. In 2008, the WHO reported that 39% and 13% of adults 20 years and older were overweight and obese, respectively (World Health Organization, 2016). In the United States of America (U.S.), it is estimated that over 30% of adults and 17% of children and adolescents are obese (Jensen et al., 2014; National Institute of Diabetes and Digestive and Kidney Diseases, 2017; World Health Organization, 2016). Further, obesity in children is of great concern since it may predict the occurrence of obesity and the associated morbidity and mortality risk in adulthood (World Health Organization, 2014). Although there have been reports of stabilization of the obesity epidemic, overweight and obesity remain associated risks for developing some of the leading causes of preventable death globally (Centers for Disease Control and Prevention, 2017; Kokkinos, 2012), including diabetes mellitus, cardiovascular diseases, musculoskeletal disorders, and certain cancers (Cobb-Clark, Kassenboehmer, & Schurer, 2014; Jensen et al., 2014; National Heart Lung and Blood Institute, 2017; World Health Organization, 2016).

The risk of obesity and its comorbidities are greatly determined by selected health behaviors (Cobb-Clark et al., 2014). Research has shown physical activity and exercise to be effective elements in the prevention and treatment of obesity (DiBonaventura & Chapman, 2008). While physical activity and exercise are often used interchangeably, they both describe different concepts (Caspersen, Powell, & Christenson, 1985). Caspersen et al., (1985) defined physical activity as “any bodily movement produced by skeletal muscles that results in energy expenditure," while exercise is defined as a subset of physical activity that is planned, structured and repetitive and has a goal of improving or maintaining health- or skill- related physical fitness. Execution of physical activity and consumption of food are essential for sustaining life, however, the amount of activity conducted or food consumed is predominantly subjective and has large inter- and intra-person variability (Caspersen et al., 1985; Vabø & Hansen, 2014). Behavioral choices related to diet and physical activity/exercise interact to have a large influence on health, as proper nutrition and adequate physical activity/exercise are vital components for the maintenance of health and prevention of disease. As such, understanding how individuals make the decisions that form their dietary patterns and how physical activity/exercise habits affect these decisions is fundamental to understanding obesity, since weight gain is primarily a result of ingested calories exceeding the amount of calories expended (Cobb-Clark et al., 2014).

Decision making is a mental process shaped by an individual's personality, behavioral characteristics and experiences, which are affected by biases, emotions, heuristics, and the environment (Leng et al., 2017). Food related decisions are made by individuals every day and include consideration of whether, what, when, where, how much, how, how long and with whom one eats (Doucerain & Fellows, 2012; Mela, 2001; Sobal & Bisogni, 2009). Food choices can be defined as the selection of foods from many alternatives for consumption, resulting from a dynamic combination of psychophysiological, sensory and situational signals (Mela, 2001; Sobal & Bisogni, 2009).

Since physical activity and exercise have been shown to have a positive effect on prevention and treatment of obesity and its comorbidities, the influence of exercise on food choices is of great interest. Most of the literature focuses on the acute effect of exercise on appetite control and food consumption, in terms of caloric intake and nutrient composition (Blundell, Gibbons, Caudwell, Finlayson, & Hopkins, 2015; Pomerleau, Imbeault, Parker, & Doucet, 2004; Vatansever-Ozen, Tiryaki-Sonmez, Bugdayci, & Ozen, 2011). However, little research has been conducted to assess the effects of physical activity/exercise on long-term food intake or on actual food choices. Knowledge of the effect of physical activity/exercise on food choices will contribute to the development of effective, individualized behavioral intervention strategies for improving dietary behaviors and overall health. Hence, the primary aim of this thesis is to determine the relationship between habitual physical activity/exercise and decisions made about food.

Statement of Purpose

The purpose of this study is to assess the relationship between habitual physical activity/exercise and decision making about the preference, type, amount and timing of food for consumption. A secondary goal is to determine whether decisions made about money, an approach primarily used to assess delayed discounting, are impacted by physical activity in a similar fashion as decisions made about food.

Aims & Hypotheses

Aim 1: Determine the relationship between physical activity and food liking and preferences for varying food types (sweet, non-sweet, fatty, non-fatty).

- Hypothesis 1a: Participants who participate in high levels of physical activity will demonstrate a *lower liking for high fat and sweet foods* when compared to participants who are less physically active or sedentary.
- Hypothesis 1b: Participants who participate in high levels of physical activity will demonstrate a *greater liking for low fat and non-sweet foods* when compared to participants who are less physically active or sedentary.

Aim 2: Investigate the relationship between habitual physical activity and food preferences related to the type (sweet vs. non-sweet, high fat vs. low fat) amount (smaller vs. larger) and timing (immediate vs. delayed).

- Hypothesis 2a: Based on previous research showing a curvilinear (J-shaped) relationship between physical activity and energy intake (Blundell, 2011; Blundell, Gibbons, Caudwell, Finlayson, & Hopkins, 2015), it is hypothesized that there will be a curvilinear relationship between physical activity and decisions made about food. Specifically, it is hypothesized that individuals who are physically inactive and those with very high activity levels will have a greater tendency to choose highly palatable foods, while the tendency to choose these foods will be lower in moderately active individuals:

I. Participants with low activity levels and those with high activity levels will *choose high fat foods more often* than those with moderate activity levels.

II. Participants with low activity levels and those with high activity levels will *choose low fat foods less often* than those with moderate activity levels.

III. Participants with low activity levels and those with high activity levels will *choose sweet foods more often* than those with moderate activity levels.

IV. Participants with low activity levels and those with high activity levels will *choose non-sweet foods less often* than those with moderate activity levels.

- Hypothesis 2b: Participants with low activity levels and those with high activity levels will be more likely to *choose larger amount of food* for consumption when compared to moderately active individuals.
- Hypothesis 2c: Participants with a low activity level and those with high activity levels will be more likely to *choose food for immediate consumption over a delayed option* when compared to moderately active individuals.

<u>Aim 3:</u> Examine the relationship between physical activity/exercise and delayed discounting for decisions made about money and food.

- Hypothesis 3a: Participants with lower levels of physical activity will *discount food more* when compared to those with higher level of physical activity.
- Hypothesis 3b: Participants with lower levels of physical activity will *discount money more* when compared to those with higher level of physical activity.

- Exploratory hypothesis 3c: Since money retains its value over time but the same is not true for non-money commodities (Stuppy-Sullivan, Tormohlen, & Yi, 2016), it is hypothesized that participants will *discount food choices to a higher degree than money*.

CHAPTER 2. LITERATURE REVIEW

Eating behavior impacts health. There is consensus among experts that chronic positive energy imbalance, i.e., an energy intake that exceeds energy expenditure, is the main contributor to the progression of obesity (Apovian, 2010; Fenzl, Bartsch, & Koenigstorfer, 2014; Klok, Jakobsdottir, & Drent, 2007; Kokkinos, 2012). Behavioral factors (food intake and physical activity) interact with biological (gene expression and hormonal regulation) and psychological mechanisms to cause obesity (Apovian, 2010; Emery & Levine, 2017; Kokkinos, 2012; Leng et al., 2017). To combat obesity and its comorbidities, many public health organizations recommend physical activity/exercise for weight loss and weight maintenance, as research has shown that mortality risks associated with obesity are attenuated by increased levels of physical activity/exercise regardless of body weight (Blundell et al., 2015; Donnelly et al., 2013; Kokkinos, 2012).

Despite ongoing educational campaigns and increased public awareness of the importance of healthy eating and being physically active, many individuals fail to achieve dietary and activity recommendations (DiBonaventura & Chapman, 2008). Furthermore, there is the public misconception that increased physical activity/exercise increases appetite and consequently food intake. However, scientific evidence does not support this claim (Bellisle, 1999; Blundell, Stubbs, Hughes, Whybrow, & King, 2003; Donnelly et al., 2014; King, Burley, & Blundell, 1994). Exercise has been found to suppress energy intake and appetite in the short term (Bellisle, 1999; Douglas et al., 2015; King et al., 1994; Martins, Morgan, & Truby, 2008; Schubert, Desbrow, Sabapathy, & Leveritt, 2013), however, it is currently unknown how physical activity/exercise affects decision making about food. As such, it is important to understand the internal and external drivers of dietary behavior and the potential outcomes associated with various levels of physical activity/exercise.

Determinants of Food Choices

Research has shown dietary behavior is affected by many interconnected factors, which also determine food choices (Prescott, Young, O'Neill, Yau, & Stevens, 2002; Shepherd, 1999; Vabø & Hansen, 2014). These factors can be summarized into product-related, consumer-related and environmental-related factors (Wądołowska, Babicz-Zielińska, & Czarnocińska, 2008). Additionally, knowledge, attitudes and beliefs about food, life stage and personal or group preference also influence the decisions made about food consumption (Vabø & Hansen, 2014). However, even though exercise has been shown to lead to more sensitive eating behavior (Martins et al., 2008), there is little research surrounding exercise as a determinant of food choice or food selection.

The consumer-related and product-related factors are of most importance to this research study, since they are directly related to the individual and the food itself. Firstly, physiological needs are the most basic component motivating our decisions about food. The human body responds to feelings of hunger and satiety to obtain the nutrients and energy needed to survive (Leng et al., 2017). Secondly, food is made up of chemical components, which impacts its palatability and sensory qualities such as taste, texture, appearance and smell (Shepherd, 1999). These elements can impact our desire to eat, the food we choose, and the quantity we eat. Finally, psychological factors such as personality, emotions and stress can also affect food choices (Roemmich, Lambiase, Lobarinas, & Balantekin, 2011; Shepherd, 1999). Psychological factors can influence the amount eaten, when it is eaten and the cravings experienced and whether individuals succumb to these cravings. Further, psychological factors may affect information processing and its translation to behavior patterns. It has been suggested that the lack of a relationship between knowledge, attitude and food choices may be due to an optimistic bias, individuals may not feel the need to change their eating habits because they may think they are at less of a risk for any adverse health outcomes (Leng et al., 2017; Shepherd, 1999).

Psychological Factors: Obesity, Exercise and Food Choices

Failure to meet dietary and physical activity recommendations leading to obesity can be influenced by psychological factors, such as personality traits. One such trait is impulsivity, the inclination to act immediately on urges regardless of the negative consequences (Emery & Levine, 2017). Impulsivity has been linked to preference for palatable foods, disinclination for delayed rewards, disinhibited behaviors, and decreased emotional control (Emery & Levine, 2017). A highly impulsive personality has been identified as one of many meaningful contributors to increasing BMI (Emery & Levine, 2017). This is reinforced by research that has shown that overweight and obese individuals have a higher preference for and probability of choosing and consuming energy-dense and highly palatable food, which may contribute to the progression and maintenance of their condition (Mela, 2001). However, this preference is highly influenced by psychological factors such as mood, emotions and stress (Mela, 2001). This suggests that food preference should not be cited on its own as a primary cause of overweight and obesity, as food liking may not dictate actual food intake (McNeil, Cadieux, Finlayson, Blundell, & Doucet, 2015; Mela, 2001).

Impulsive decision making is also associated with delayed discounting, the degree to which a more delayed outcome has less value (Odum, 2011; Sofis, Carrillo, & Jarmolowicz, 2017; Sze, Slaven, Bickel, & Epstein, 2017), as more impulsive individuals tend to prefer more immediate outcomes (Sze et al., 2017). Similarly, individuals with a high locus of control - an individual's perception of control over the outcomes of the decisions they make (Cobb-Clark et al., 2014; Shepherd, 1999) - were found to be more likely to eat healthy, be physically active, and future-oriented and less likely to discount future rewards (Cobb-Clark et al., 2014). Delayed discounting is typically measured using binary choices between smaller immediate rewards and larger delayed rewards (Odum, 2011; Sze et al., 2017). Research has shown steeper discounting rates to be associated with obesity (Ely, Howard, & Lowe, 2015; Stuppy-Sullivan et al., 2016). For example, in the case of obesity, the reward of weight loss is delayed since noticeable weight loss as a result of healthy eating and increased physical activity occurs gradually (Sze et al., 2017). Weight loss is facilitated by a decrease in impulsive choices which may entail choices such as, forgoing a preferred palatable food or engaging in physical activity/exercise in place of watching television (Sze et al., 2017). Fortunately, physical activity/exercise has been shown to reduce the occurrence of delayed discounting for monetary reward (Sofis et al., 2017). Sofis et al. (2017) reported that their effort-paced physical activity intervention maintained reductions in delayed discounting for money over time and were positively associated with physical activity adherence and improvements in fitness level.

Physiological Factors:

1. *Exercise and Hedonic Control of Food Intake*

Obesity is strongly related to hedonic mechanisms, which are stimulated by the sensory pleasure of eating palatable food and may result in increased food intake (Martins et al., 2008). Weight gain can be a result of hedonic mechanisms overriding physiological cues for meal termination by stimulating food consumption or overeating (Alonso-Alonso et al., 2015; Emery & Levine, 2017; Leng et al., 2017). An important endocrine factor in the hedonic system is dopamine (Graham Finlayson & Dalton, 2012), a neurotransmitter linked to food intake, reward and mood (Singh, 2014). Dopamine reinforces pleasure from food and contributes to cravings (Alonso-Alonso et al., 2015). Consequently, food reward anticipation is a learnt behavior which results in elevated dopamine levels (Alonso-Alonso et al., 2015; Singh, 2014). If overstimulated by highly palatable foods, particularly for high fat or sugar foods, the dopamine reward pathway in the brain may be dampened, which may increase reward seeking behavior and lead to overeating (Alonso-Alonso et al., 2015; Singh, 2014). Since exercise has been found to reduce intake of drugs and alcohol in humans (Alonso-Alonso et al., 2015), exercise might also have the capacity to serve as an intervention for reducing food intake as a result of food reward cues.

Exercise may act as a control mechanism for food intake (Martins et al., 2008). Donnelly et al. (2013) reported that engaging in supervised physical activity alone was shown to be more effective than caloric restriction at producing clinically significant weight loss and conserving fat free mass for both men and women. Fearnbach et al. (2015) demonstrated that an acute bout of exercise decreased neural responses to food cues with a subsequent reduction in energy intake in obese adolescents. Furthermore, McNeil et al. (2015) demonstrated that acute exercise lead to a decreased preference for high fat food and resistance exercise specifically decreased hedonic liking for high fat foods. More research is needed to understand the long-term effects of exercise on food intake and its influence on food choices.

2. Homeostatic Control of Food Intake and Exercise

As previously stated, food intake and physical activity are two of the major factors involved in weight control, as such the role of appetite regulation on eating behavior and the changes that may occur with exercise are important. Appetite is a psychological construct and refers to the desire to eat. It controls energy intake to maintain physiological needs. Appetite is modulated by the interaction between the brain, digestive system and adipose tissue (Bellisle, 1999). The hypothalamus regulates appetite, maintaining energy homeostasis (Martins et al., 2008). Hormones controlled by the hypothalamus include leptin, ghrelin, peptide YY (PYY), adiponectin and glucagon-like peptide-1 (GLP-1), among others (Austin & Marks, 2009; Perry & Wang, 2012). These hormones together impact hunger, appetite, cravings and weight. Leptin, PYY, and GLP-1 are considered anorexigenic (appetite suppressing), since they may modulate gastric emptying, stimulate a decrease in food intake and/or increase energy expenditure (Austin & Marks, 2009; Martins et al., 2008; Perry & Wang, 2012). Ghrelin induces orexigenic effects (appetite stimulating), which act to signal the need for increased food intake (Austin & Marks, 2009; Perry & Wang, 2012). The response of these hormones to exercise appears to be highly dose dependent, with more noticeable changes achieved with intense bouts of exercise (Crabtree, Chambers, Hardwick, & Blannin, 2014; Douglas et al., 2015; Martins et al., 2008).

Many studies have shown that in response to acute exercise the neuroendocrine system may be suppressed with an associated reduction in hunger and food intake in the short term (Bellisle, 1999; Martins et al., 2008). However, there are conflicting results regarding the post-exercise effect on appetite suggesting that this response may be affected by eating behavior, body weight and sex. In a study conducted by Pomerleau et al. (2004), women were found to have increased energy intake at lunch time following a high-intensity exercise, which also approached complete compensation for exercise induced energy expenditure, although there was no increase at dinner time. In contrast, Douglas et al. (2015) found no significant change in appetite, satiety, energy or micronutrient intake in response to two consecutive days of aerobic exercise in healthy young men. Further research needs to be done to determine the relationship between appetite and food choices.

Summary

The desire to eat is regulated by both homeostatic and hedonic mechanisms. The homeostatic mechanisms regulate the body's feeding circuitry, which monitors energy needs as well as subjective hunger and satiety. However, the body's hedonic mechanisms, which control the brains reward circuitry responsible for wanting and liking, can supersede the homeostatic mechanisms. Together the homeostatic and hedonic mechanisms influence an individual's eating habits which in turn control food intake and food choices. The drive to eat in the absence of an energy deficit, caused by hedonic mechanisms, is a major contributor to obesity. Fortunately, research has shown that physical activity/exercise positively affect both the homeostatic and hedonic mechanisms in relation to weight loss and obesity; however, little is known about the impact of exercise on actual food choices. As such, this study seeks to understand the relationship between habitual physical activity/exercise on food choices.

CHAPTER 3. APPROACH

The overall purpose of this thesis was to understand the relationship between habitual exercise and food choices. To investigate this relationship, a cross-sectional study was conducted in students attending the University of Nebraska-Lincoln (UNL).

Participants

Participants were recruited from UNL via the SONA Systems website, a web-based program used to coordinate psychology research. To be eligible for the study, participants had to be enrolled in a course offered by the Department of Psychology at UNL at the time of data collection. Participants received 2 extra credits toward one of their classes within the psychology department upon successful completion of the study visit. Participants provided written informed consent prior to enrollment in the study. To maintain consistency of psychophysiological state and ensure accurate results, all participants were required to abstain from eating for at least 3 hours prior to their scheduled time slot and to abstain from exercise on the day prior to arrival at the research site.

Study Design

Data were collected over the course of two semesters (Fall - Study sample 1 and Spring - Study sample 2) towards the end of the semester to maximize recruitment through the provision of extra credit. Upon consenting to participate in the study, participants completed an electronic, self-administered questionnaire. Anthropometric data were collected after completion of the questionnaire to avoid priming participants to choose healthier food options. A structured electronic questionnaire was used to evaluate choices and judgments about food, physical activity, and money. The questionnaire was comprised of nine (9) sections: demographics, previous meal time and psychophysiological state, physical activity, food preferences, food choices, food titrations, money titration, money similarities based on amounts, and money similarity over time. For the exception of the demographic and physical activity sections, all questions within each of the other individual sections were randomized for each participant. Demographic, anthropometric, and physical activity data were used as independent variables for analysis.

Anthropometry

A digital column scale with stadiometer (SECA 769) was used to measure height and weight, respectively. Height and body weight were measured according to the protocol of the International Society for the Advancement of Kinanthropometry (Marfell-Jones, Olds, Stew, & Carter, 2006). Height were measured to the nearest 0.1 centimetres (cm) in bare feet with participants standing upright against the stadiometer. Weight was measured to the nearest 0.1 kilogram (kg) with participants standing lightly dressed on the digital scale. Waist and hip circumference were measured using a non-stretch measuring tape (Marfell-Jones et al., 2006). Waist circumference was measured to the nearest 0.1 cm at the mid-point between the lowest rib and the top of the iliac crest at minimum inspiration. Hip circumference was measured to the nearest 0.1 cm over minimal clothing at the maximal extension of the buttocks at the level of the greatest protrusion of the gluteal muscles (Marfell-Jones et al., 2006).

Physical Activity

The short form of the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003), was used to assess the estimated level of activity of the participants over seven days. Additionally, time spent participating in exercise and sports specific activities was also assessed according to the type of exercise or sport, frequency of participation (days/week) and daily duration of each performed activity over seven days.

Metabolic equivalent of task (MET) is a simple physiological measure of the energy required for physical activity and MET minutes represent the time spent participating in physical activity in relation to the amount of METs (Bushman, 2012). Conversion of physical activity in to MET minutes allows researchers to assess the intensity of physical activity (Bushman, 2012). MET minutes were calculated using the following equations:

- Vigorous activity MET minutes: vigorous activity minutes x days per week x 8
- Moderate activity MET minutes: moderate activity minutes x days per week x 4
- Walking MET minutes: walking minutes x days per week x 4

In addition, exercise activity MET minutes were calculated for exercise/sport activities using corresponding MET values from the Compendium of Physical Activity (Ainsworth et al, 2011)

Physical activity was divided into quintiles for analysis which ranged from very low activity (≤1140 METmins) to very high activity (≥5588 METmins). Similarly, exercise was divided into 5 groups, the first was a non-exercisers group (0 METmins) and the remaining participants were divided into equal quartiles ranging from low activity (≤464 METmins) to very high activity (≥2334 METmins).

Food preferences and food choices

The assessment of food liking, food preferences, and temporal food discounting made use of visual food cues. For the food liking and preference, the visual cue used were approximately 350 kcal per item. Each question contained labelled pictures of the plated food items. For these sections, 8 food items were chosen and categorized as high or low fat content and/or sweet or non-sweet foods. The proposed foods were pizza, French fries, spaghetti with tomato sauce (meatless), chicken and veggie bowl with rice, double fudge brownie with icing, vanilla ice cream, fruit bowl and oatmeal parfait (Figure 3.1). The food selection was guided by foods used in previous studies (Graham Finlayson et al., 2011; McNeil et al., 2015), although certain foods were replaced to be more suitable for an American population. Additionally, the palatability, macronutrient make up and caloric content of the foods were considered.

Figure 3.1 Food Items Used for the Questionnaire

Food liking: Participants were asked to rank each food on a scale of 0 – 10 as a measure of food liking (Figure 3.2). Food liking scores were calculated as an average frequency of choice for all foods grouped into each of the following categories; high fat, low fat, sweet, non- sweet.

Food liking

Figure 3.2 Sample Food Liking Question

Food preference: Participants were asked to select between two food options, for the range of all possible food combinations. Choices were presented once for immediate consumption, for delayed consumption in 4h (a typical time between meals), and between one food for immediate and one for delayed consumption (Figure 3.3). For delayed options, participants were instructed that they should make the decision under the assumption that they would not eat any food until the next meal. Foods were categorized according to high fat, low fat, sweet and non-sweet. The non-selected foods were assigned a score of 0 and the selected foods were assigned a score of 1. Mean scores were calculated for each group (high fat, low fat, sweet, non-sweet) for analysis.

Food amount: Participants were asked to choose their ideal portion size for both immediate and delayed consumption for each food item. Food portions ranged from 75-450 kcals.

Figure 3.3 Sample Food Preference Questions

Food discounting: Participants were asked to make binary choices between consuming a smaller portion of food that is available for immediate consumption and a larger portion of the same food after a delayed time (4 hrs.; Figure 3.4), assuming they will not be able to eat anything until their next meal if the delayed option is chosen. The immediate options were gradually decreased in amount from the largest portion (450-750 kcal) to the smallest possible portion (75 kcal). This procedure was repeated for each food option. Smaller, immediate options were given a score of 0 and larger, delayed options a score of 1. An estimate of the participants' delayed discounting was made from the pattern of choices. This method has been used in previous studies (Amlung, Petker, Jackson, Balodis, & MacKillop, 2016).

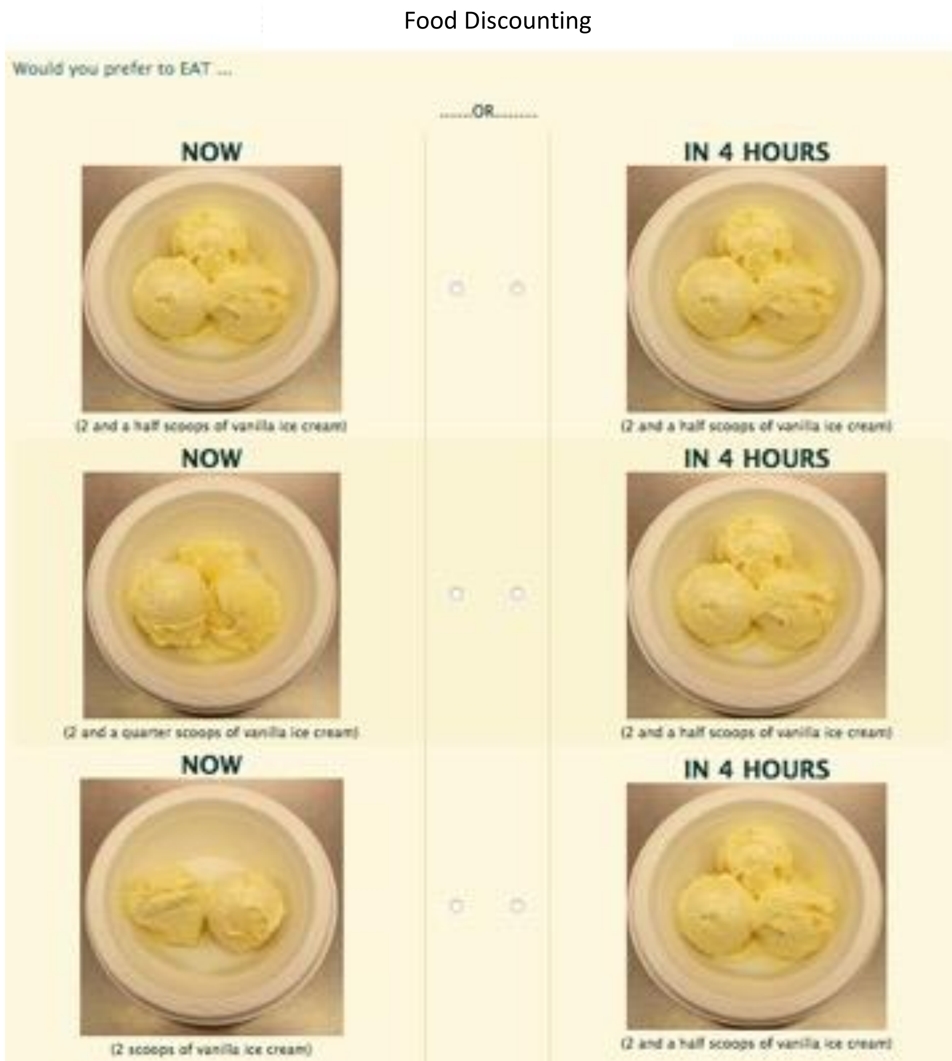

Figure 3.4 Sample Food Delayed Discounting Question

Delayed Discounting – Monetary Choices

To assess delayed discounting regarding monetary choices, participants were presented with two hypothetical amounts of money to be received: one which was available immediately or a larger amount which is available only after a time delay. The immediate options were gradually decreased in amount from the a maximum of $10 to the minimum of $1. This was repeated for delays of 2, 7, 14, 30, 90 and 365 days. As with the food titration, smaller, sooner options were given a score of 0 and larger, later options a score of 1. This is consistent with previous studies which have used similar methods (Odum, 2011; Stuppy-Sullivan et al., 2016).

Statistical Analysis

Based on their habitual activities, participants were classified as non-exercising or divided into activity quartiles based on physical activity (expressed in MET minutes) and exercise time (in min/d). Statistical analysis was performed with R Statistical Software (version 3.3.2). Differences in outcome variables (food liking, food preferences and food and money discounting) were assessed using ANOVA to test for difference between groups for physical activity level and exercise. ANOVA analyses were conducted using BMI, WHR and gender as covariates. Effects for covariates were only reported when significant; otherwise, only the significances for primary outcome variables were reported. To assess delayed discounting, area under the curve analysis was used. Pearson’s product-moment correlation was used to determine the relationship between food and money discounting. Statistical significant was set at $p<0.05$.

CHAPTER 4. RESULTS

Section 1

Participants and Anthropometrics

The analysis included 174 participants. Demographic characteristics of the participants are summarized in Table 4.1. In the full sample, over three-quarters of the participants were female (78.7%) and White/Caucasian (79.9%). Over half of the participants were undergraduate students (68.4%) and the annual parental income varied considerably.

Table 4.1 Demographic characteristics of participants (total N = 174)

Variable	**% (n)**
Gender	
Females	78.7 (137)
Males	21.3 (37)
Racial/Ethnic Identity	
White/Caucasian	79.9 (139)
Hispanic/Latino	8.0 (14)
Asian	7.5 (13)
Black	2.3 (4)
Other	1.7 (3)
American Indian/Native American	0.6 (1)
Employment Situation	
Undergraduate Student	68.4 (119)
Part-Time Employment	25.9 (45)
Full-time Employment	2.9 (5)
Unemployed/Looking for Work	2.9 (5)
Annual Parental Income	
>$100,000	29.3 (51)
$75,001-$100,000	20.7 (36)
$50-001-$75,000	17.2 (30)
$25,001-$50,000	13.8 (24)
<$25,000	8.0 (14)
Preferred not to answer	10.9 (19)

The participants' anthropometric characteristics are summarized in Table 4.2. The mean age (± SD) of the participants were 20.1 ± 2.51 years old. More than half of the participants were within the normal weight category for body mass index (BMI), while over three-quarters of the participants fell into the low risk categories for both waist circumference (WC) and waist-to-hip ratio (WHR). Male had a significantly higher weight ($p<0.001$), height ($p<0.001$), WC ($p<0.001$) and WHR (<0.001).

Table 4.2 Anthropometric characteristics of participants (mean ± SD)

Variable	**Total (N=174)**	**Female (n = 137)**	**Male (n = 37)**
Age (years)	20.1 ± 2.51	20.2 ± 2.7	20.0 ±1.6
Weight (kg)	71.2 ± 16.5	67.9 ± 15.3	83.7 ± 14.7***
Height (cm)	168.2 ± 9.0	165.2 ± 7.0	179.6 ± 5.6***
BMI (kg/m^2)[a]	25.1 ± 5.1	24.8 ± 5.3	26.0 ± 4.5
Underweight (<18.5)	1.7% (3)	2.2% (3)	0% (0)
Normal Weight (18.5-24.9)	56.3% (98)	59.1% (81)	45.9% (17)
Overweight (25 – 29.9)	29.9% (52)	24.8% (34)	48.6% (18)
Obese (>30)	12.1% (21)	13.9% (19)	5.4% (2)
Waist Circumference (cm)	80.1 ± 12.3	78.1 ± 11.5	87.3 ± 12.7***
Low Risk (Females < 88, Males < 102)[a]	87.4% (152)	86.1% (118)	91.9% (34)
High Risk (Females >88, Males < 102	12.6% (22)	13.9% (19)	8.1% (3)
Waist to Hip Ratio	0.78 ± 0.07	0.76 ± 0.06	0.84 ± 0.06***
Low Risk (Female < 0.85, Male <0.90)[a]	92.0% (160)	92.0% (126)	91.9% (34)
High Risk (Female ≥0.85, Male ≥0.90)	8.0% (14)	8.0% (11)	8.1% (3)
Weight Gained/Lost			
Lost	26.4% (46)	29.2% (40)	16.2% (6)
Gained	35.6% (62)	32.1% (44)	48.6% (18)
Neither	37.9 (66)	38.7% (53)	35.1% (13)
Future Weight Goals			
Lose	59.2% (103)	64.2% (88)	40.5% (15)
Gain	8.0% (14)	3.6% (5)	24.3% (9)
Neither	32.8% (57)	32.1% (44)	35.1% (13)

[a] World Health Organization (WHO) (2008)
***Difference between female and males, $p<0.001$

Physical Activity and Exercise

Physical activity (PA) and exercise activity (EX) MET minutes calculated from self-reported data are reported in Table 4.3. There was no statistically significant difference between males and females for PA or EX (all p>0.5). PA was moderately correlated to all three of its components, vigorous activity (VA) (r=0.65; p<0.001), moderate activity (r=0.46; p<0.001) and walking activity (r=0.67; p<0.001), as seen in Figure 4.1. For EX, there was a moderate correlation between PA (0.51; p<0.001), VA (0.63; p<0.001) and moderate activity (0.36; p<0.001) but a very weak correlation with walking activity (0.04; p>0.05) (Figure 4.1).

Table 4.3 Physical Activity and Exercise METmins of participants (mean ± SD)

Activity	**Total (n=174)**	**Females (n=137)**	**Males (n=37)**
Physical Activity	3577 ± 3092	3432 ± 3144	4114 ± 2868
Vigorous Activity	1736 ± 2165	1551 ± 2045	2246 ± 2426
Moderate Activity	699 ± 919	679 ± 981	775 ± 630
Walking Activity	1949 ± 2192	2035 ± 2375	1635 ± 1300
Exercise Activity	2035 ± 3918	2020 ± 4359	2090 ± 1411

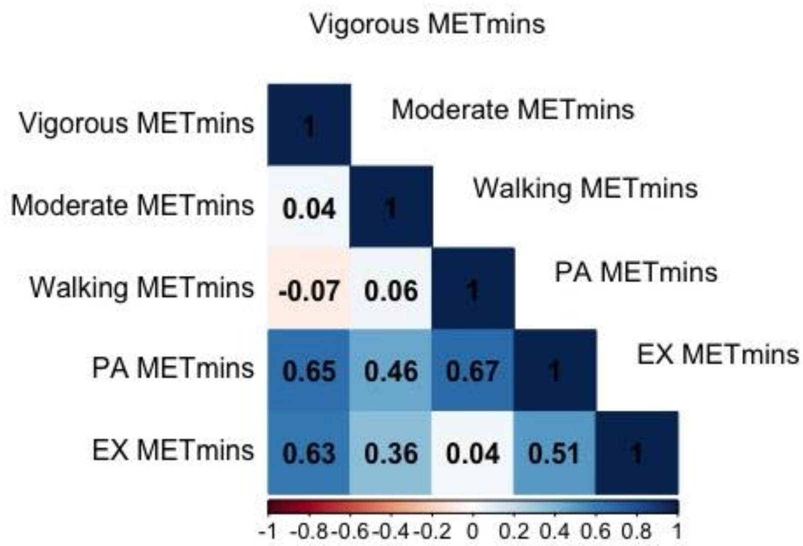

Figure 4.1 Correlation between physical activity and exercise activity.

Graphical representation of the PA and EX distribution and grouping can be seen in Figures 4.2 and 4.3. Despite having a high proportion of female participants, male participants were observed to have higher PA and EX levels than female participants as seen in Table 4.4.

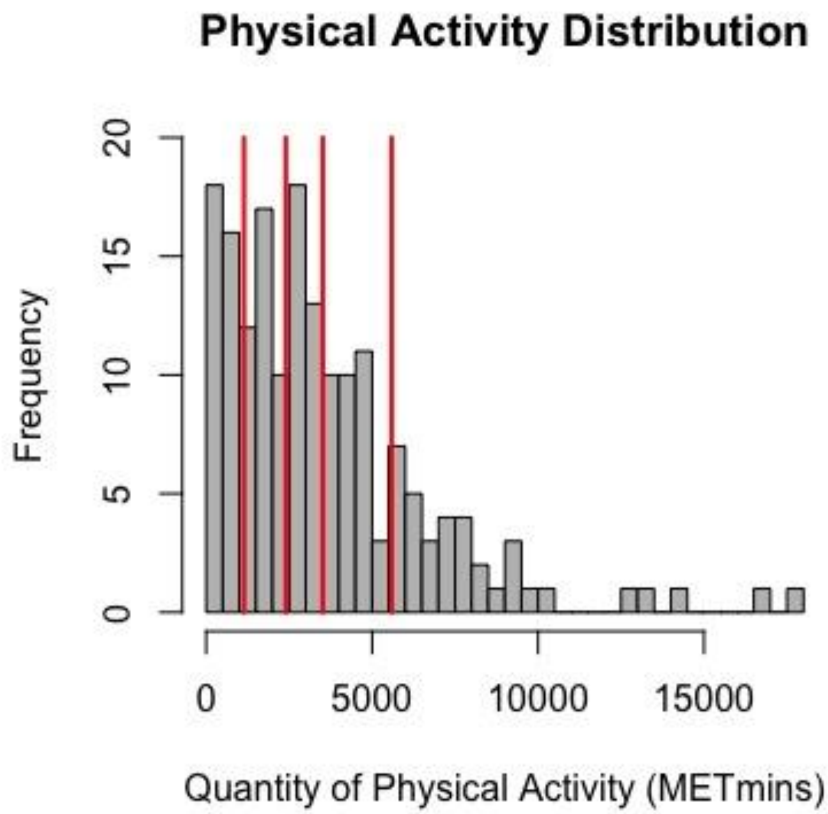

Figure 4.2 Participants' physical activity distributions and quintiles.

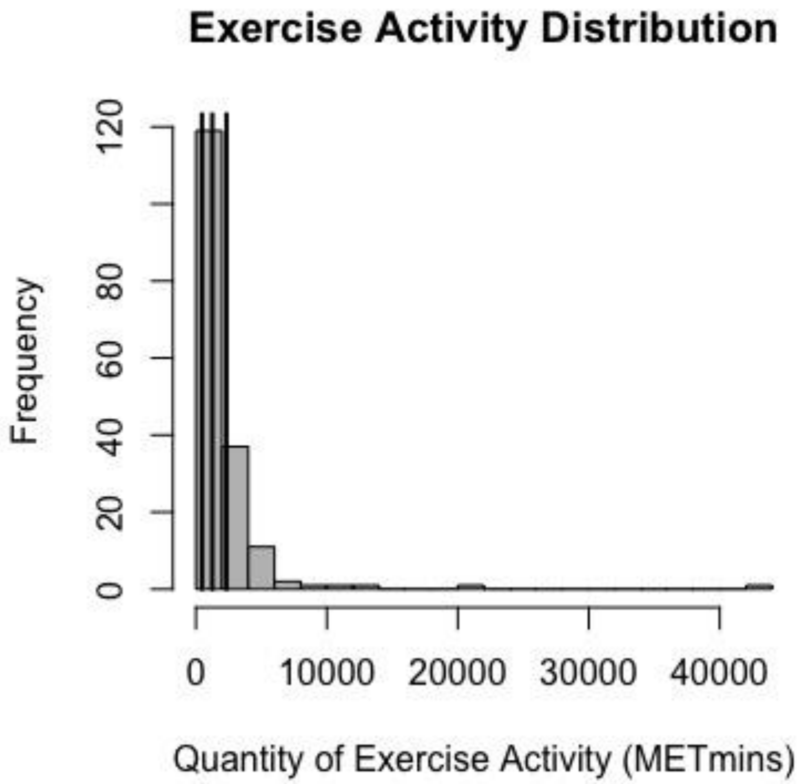

Figure 4.3 Participants' exercise activity distributions and quartiles.

Table 4.4 Physical Activity and Exercise Quintiles of participants based on calculated METmins.

Activity	Total	Females	Males
PA mins (mean(SD))			
Very Low Activity (≤ 1140 METmins)	35	31	4
Low Activity (1141-2400 METmins)	33	28	5
Moderate Activity (2401-3512 METmins)	36	28	8
High Activity (3513 – 5588 METmins)	35	25	10
Very High Activity (≥ 5588 METmins)	35	25	10
EX mins (mean(SD))			
No exercise (0 METmins)	31	29	2
Low (≤ 464 METmins)	33	28	5
Moderate (435-1249 METmins)	38	32	6
High (1250-2333 METmins)	36	21	15
Very High (≥ 2334 METmins	36	27	9

Food Liking and Food Preferences

Food liking was measured by a rating on a scale from 0 – 10, with 0 being the lowest and 10 being the highest. The mean food liking for each food type are seen in Table 4.5. Overall, participants had a higher liking for low fat over high fat foods ($p = 0.002$) and a higher liking for non-sweet over sweet foods ($p<0.001$). There were no statistically significant gender differences for food liking.

Table 4.5 Overall Food Liking of participants for individual food groups (mean ± SD).

Liking (1-10)	**Total (n=174)**	**Female (n=137)**	**Male (n=37)**
Low Fat	6.6 ± 1.5[a]	6.5 ± 1.5	6.8 ± 1.3
High Fat	5.9 ± 1.9	6.0 ± 1.9	5.7 ± 1.7
Non-Sweet	6.7± 1.4[b]	6.7 ± 1.4	6.9 ± 1.1
Sweet	5.8 ± 1.7	5.8 ± 1.8	5.7 ± 1.5

[a] Different from high fat, $p<0.01$.
[b] Different from sweet, $p<0.01$.

Food preference was measured as the average number of times a food was chosen and reported on a scale from 0-1. The mean food preference score for immediate and delayed (in 4 hours) food choices are shown in Table 4.6. Participants preferred low fat over high fat foods and non-sweet over sweet foods two-thirds of the time for immediate consumption and three-quarters of the time for delayed consumption. When immediate preference scores were compared to delayed preference scores, it was found that participants had a higher preference for low fat over high fat foods ($p<0.001$) and non-sweet over sweet foods ($p<0.001$) when given a time delay. Gender differences for preference scores were not statistically significant.

Table 4.6 Overall Food Preference of participants for immediate and delayed choices (mean ± SD).

Preference (0-1)	**Total (n=174)**	**Female (n=137)**	**Male (n=37)**
Immediate			
High Fat (0) vs. Low Fat (1)	0.66 ± 0.26	0.65 ± 0.27	0.68 ± 0.25
Sweet (0) vs. Non-Sweet(1)	0.65 ± 0.25	0.65 ± 0.25	0.65 ± 0.23
Delayed (in 4 hours)			
High Fat (0) vs. Low Fat (1)	0.72 ± 0.22[a]	0.72 ± 0.23	0.74 ± 0.20
Sweet (0) vs. Non-Sweet (1)	0.72 ± 0.21[a]	0.72 ± 0.21	0.74 ± 0.19

[a] Different from immediate preference, $p<0.001$

Aim 1: Determine the relationship between physical activity/exercise and food liking for varying food types (sweet, non-sweet, fatty, non-fatty).

Food Liking

Figures 4.4 and 4.5 show overall food liking scores according to PA and EX, respectively. Liking for different food types were not statistically different between PA categories. Conversely, the overall liking for low-fat foods was significantly higher among those who exercised at high and very high volumes when compared to non-exercisers (Figure 4.5). There were no statistically significant differences between EX groups for liking of high fat, sweet, or non-sweet foods.

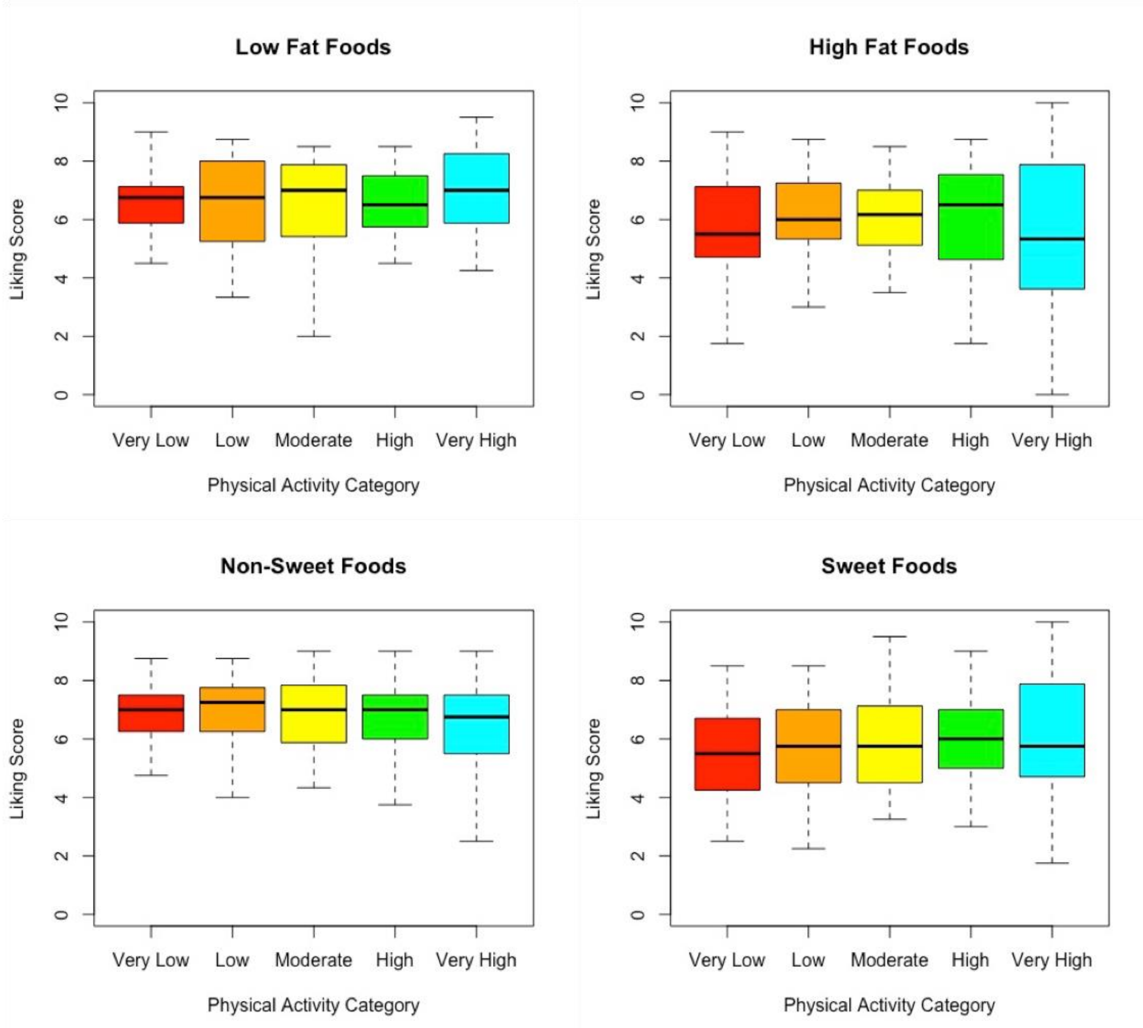

Figure 4.4 Overall liking for food types based on physical activity categories.

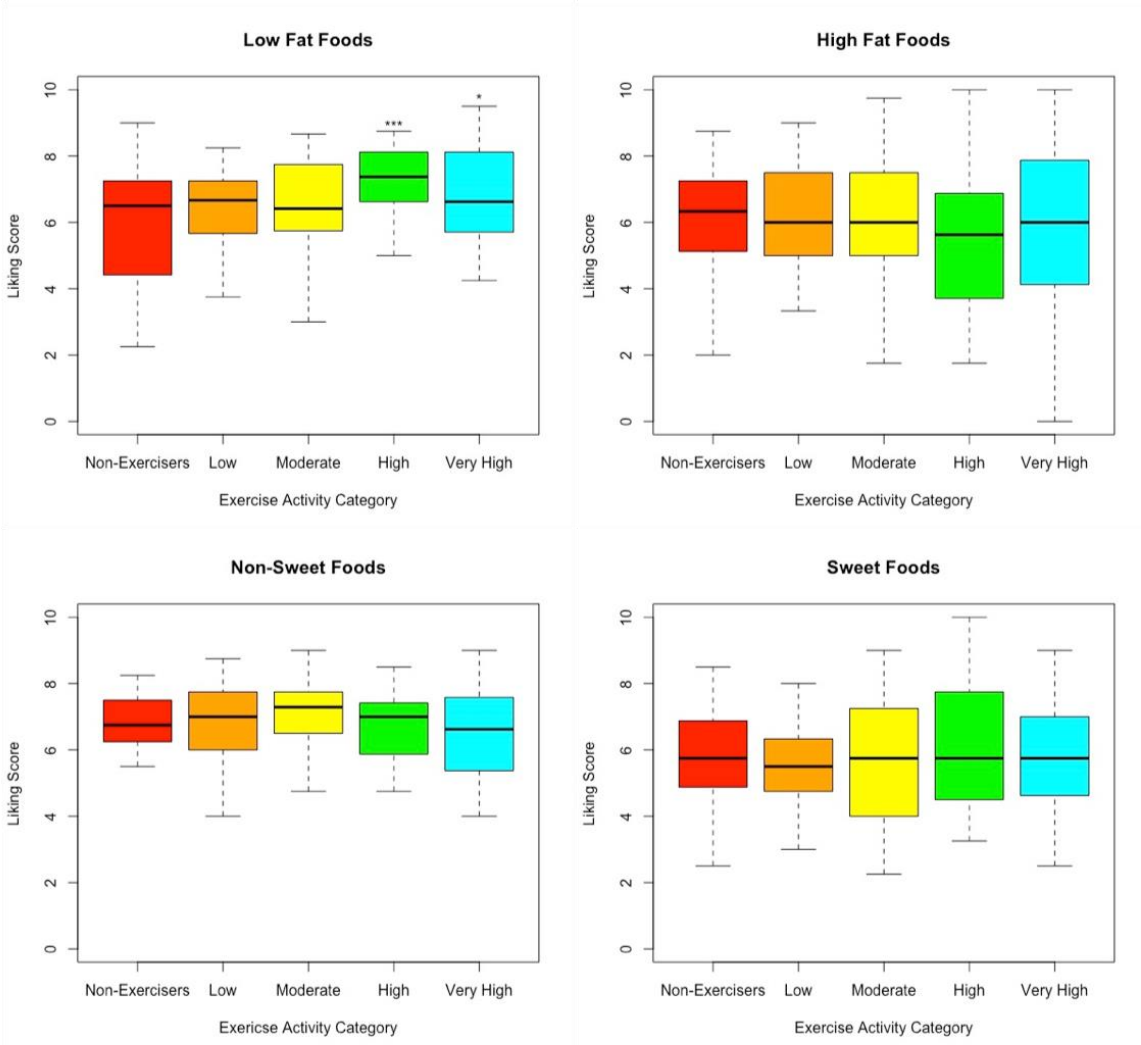

*Figure 4.5 Overall liking for food types based on exercise activity categories (*p<0.05 & ***p<0.001 when compared to non-exercisers).*

Aim 2: Investigate the relationship between habitual physical activity/exercise and food preferences related to the type (high fat vs. low fat, sweet vs. non-sweet), amount (smaller vs. larger) and timing (immediate vs. delayed).

Food Type Preference

Preferences for each food type were assessed separately for immediate and delayed consumption. The relative preference for high fat vs. low fat and sweet vs non-sweet foods between PA and EX categories at different time points are presented in Figures 4.6 and 4.7, respectively. Participants with very high levels of PA had a lower preference for non-sweet over sweet foods for immediate consumption when compared to those with very low levels of physical activity (p=0.033). There were no statistically significant differences between PA groups for low fat over high fat food preference. When BMI was adjusted for PA, underweight participants were found to have a lower preference for low fat foods over high fat foods (p=0.014) for immediate consumption when compared to normal weight participants.

Participants' preference for immediate consumption of low fat over high fat foods was significantly greater for those who exercised at high volumes (0.007) when compared to non-exercisers. Similarly, those exercising at high volumes had a greater preference for low fat over high fat foods when making the choice for delayed consumption (p=0.002) when compared to non-exercisers. There were no statistically significant differences between exercise groups for sweet over non-sweet food preference.

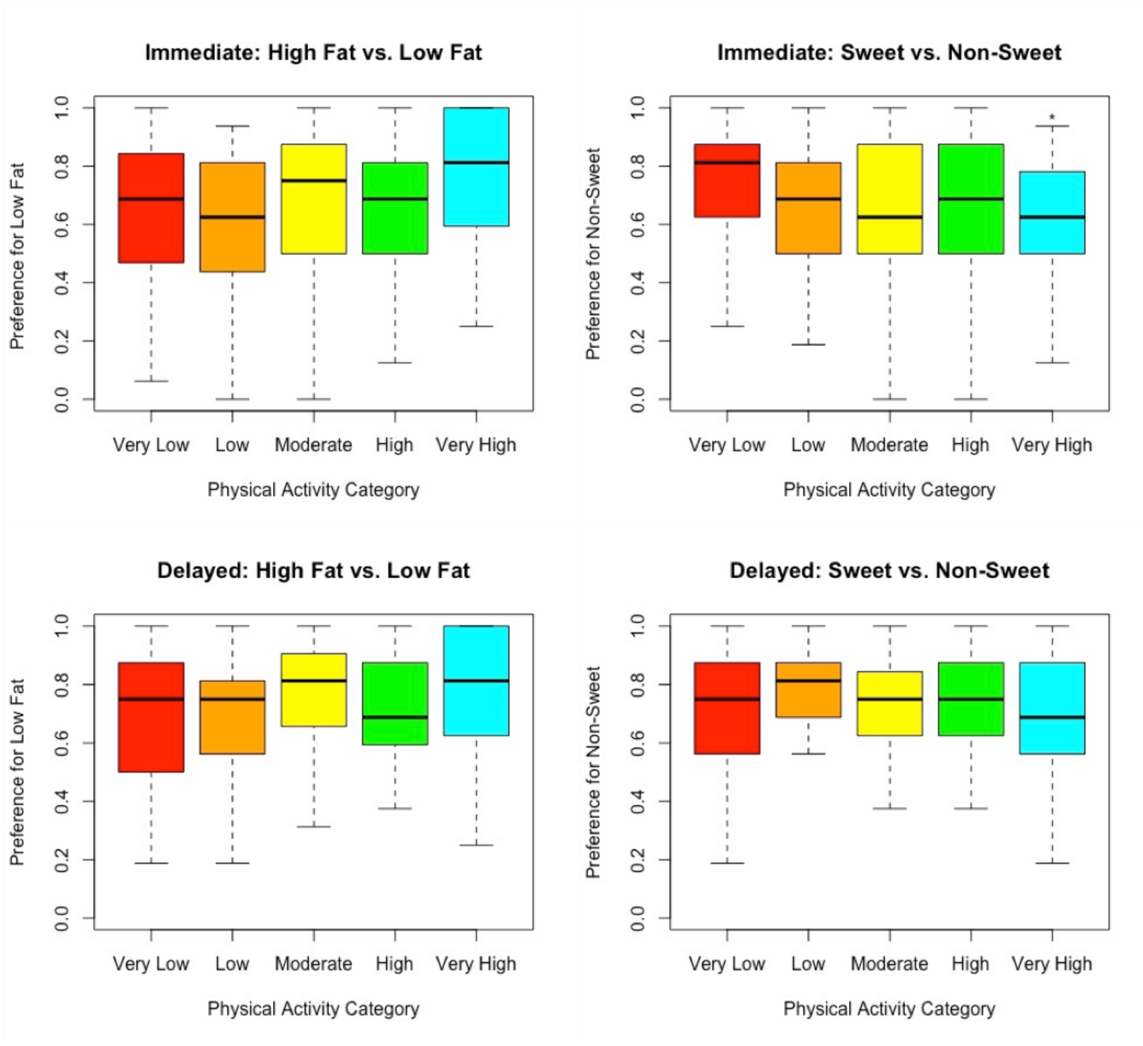

*Figure 4.6 Relative preference for high fat (0) vs. low fat (1) and sweet (0) vs non-sweet (1) foods between physical activity categories for immediate and delayed consumption (*p<0.05 when compared to participants with very low physically active levels).*

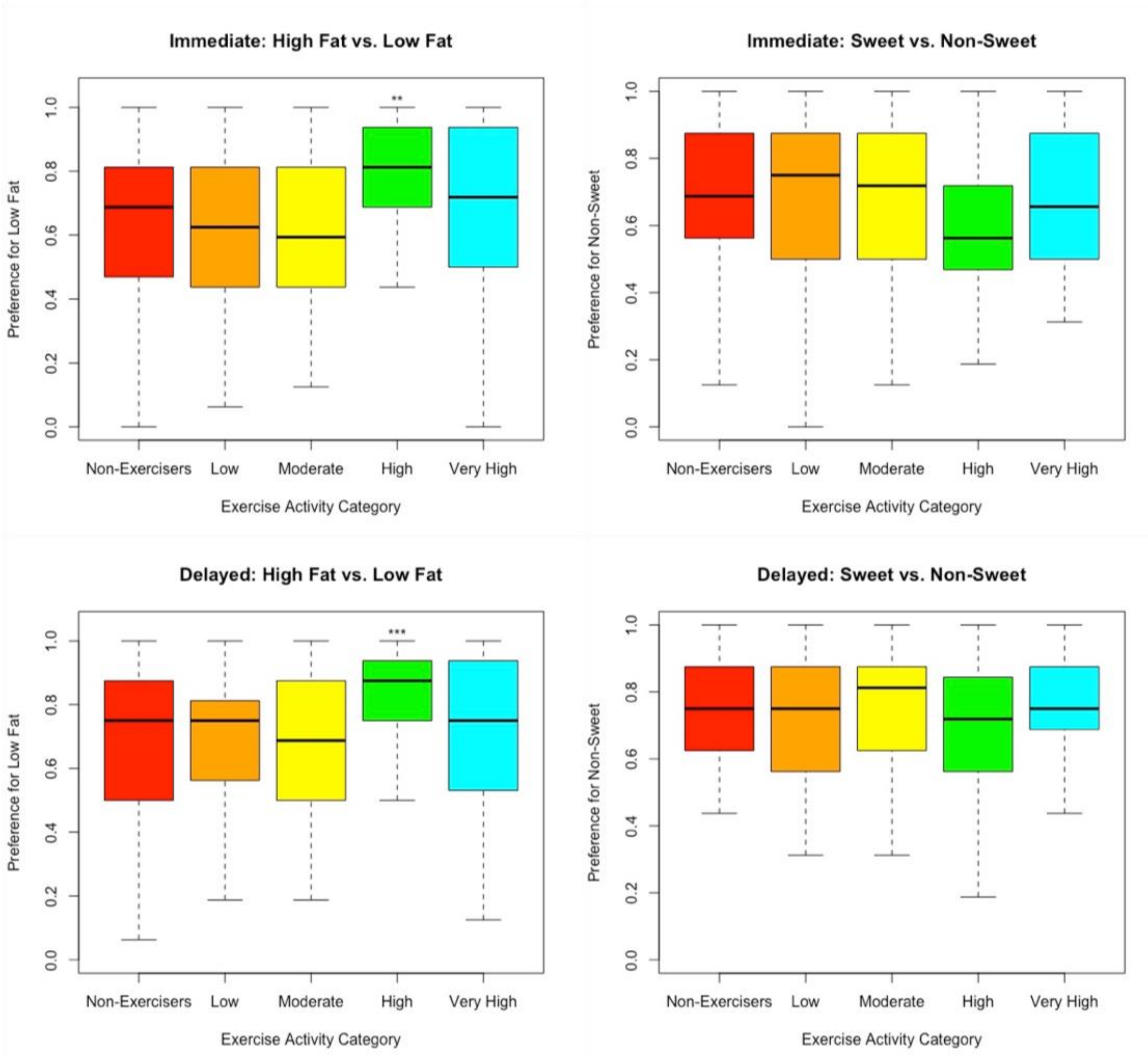

*Figure 4.7 Relative preference for high fat (0) vs. low fat (1) and sweet (0) vs non-sweet (1) foods between exercise activity categories for immediate and delayed consumption (**p<0.01 & ***p<0.001 when compared to non-exercisers).*

Food Type and Time Preference

The preferences for a standardized portion (350 kcals) of high fat vs. low fat and sweet vs. non-sweet food were assessed in relation to the time offered. Table 4.8 shows the means for food preferences when given the choice between immediate consumption vs. delayed consumption. One-quarter of the time, participants preferred high fat foods for delayed consumption over low fat foods for immediate consumption. Whereas, two-thirds of the time participants preferred low fat foods for delayed consumption over high fat foods for immediate consumption. One third of the time, participants preferred sweet foods for delayed consumption over non-sweet foods for immediate consumption. When the options were reversed, participants preferred non-sweet foods for delayed consumption over half of the time compared to sweet foods for immediate consumption.

Table 4.7 Overall Food Preference of participants for immediate vs. delayed choices (mean ± SD).

Food Preference: Immediate vs. Delayed (0-1)	**Total (n=174)**	**Female (n=137)**	**Male (n=37)**
Low Fat (0) vs. High Fat (1)	0.24 ± 0.25	0.24 ± 0.25	0.23 ± 0.25
High Fat (0) vs. Low Fat (1)	0.62 ± 0.26[a]	0.62 ± 0.27	0.62 ± 0.25
Non-Sweet (0) vs. Sweet (1)	0.29 ± 0.25	0.30 ± 0.26	0.29 ± 0.21
Sweet (0) vs. Non-Sweet (1)	0.54 ± 0.22[b]	0.54 ± 0.22	0.54 ± 0.22

[a] Different from low fat vs. high fat, p<0.001.
[b] Different from non-sweet vs. sweet, p<0.001.

There were no statistically significant gender differences found for immediate vs. delayed food preferences. However, a statistically significant difference (p<0.001) in preference score was observed between low fat foods for immediate consumption over high fat foods for delayed consumption when compared to high fat foods for immediate consumption over low fat foods for delayed consumption. Similarly, the difference in preference scores between non-sweet foods for immediate consumption over sweet foods for delayed consumption when compared to sweet foods for immediate consumption over non-sweet foods for delayed consumption was statistically significant ($p<0.001$).

Figures 4.8 and 4.9 show relative food preference scores of food type for immediate vs. delayed consumption according to PA and EX, respectively. There were no statistically significant differences between PA groups for preferences for low fat over high fat foods, high fat over low fat foods or sweet over non-sweet foods for immediate versus delayed consumption, respectively. However, participants in the very high PA group had a higher preference for sweet foods for delayed consumption over non-sweet foods for immediate consumption when compared to participants in the moderate PA group ($p = 0.02$) and very low PA group ($p=0.01$).

Participants in the high EX group had a lower preference for high fat foods for delayed consumption over low fat foods for immediate consumption when compared to participants who engaged in moderate EX ($p=0.003$) and non-exercisers ($p=0.02$). Consistently, highly active exercisers had a greater preference for low fat foods for delayed consumption over high fat foods for immediate consumption when compared to participants who engaged in moderate EX ($p=0.006$) and non-exercisers ($p=0.02$).

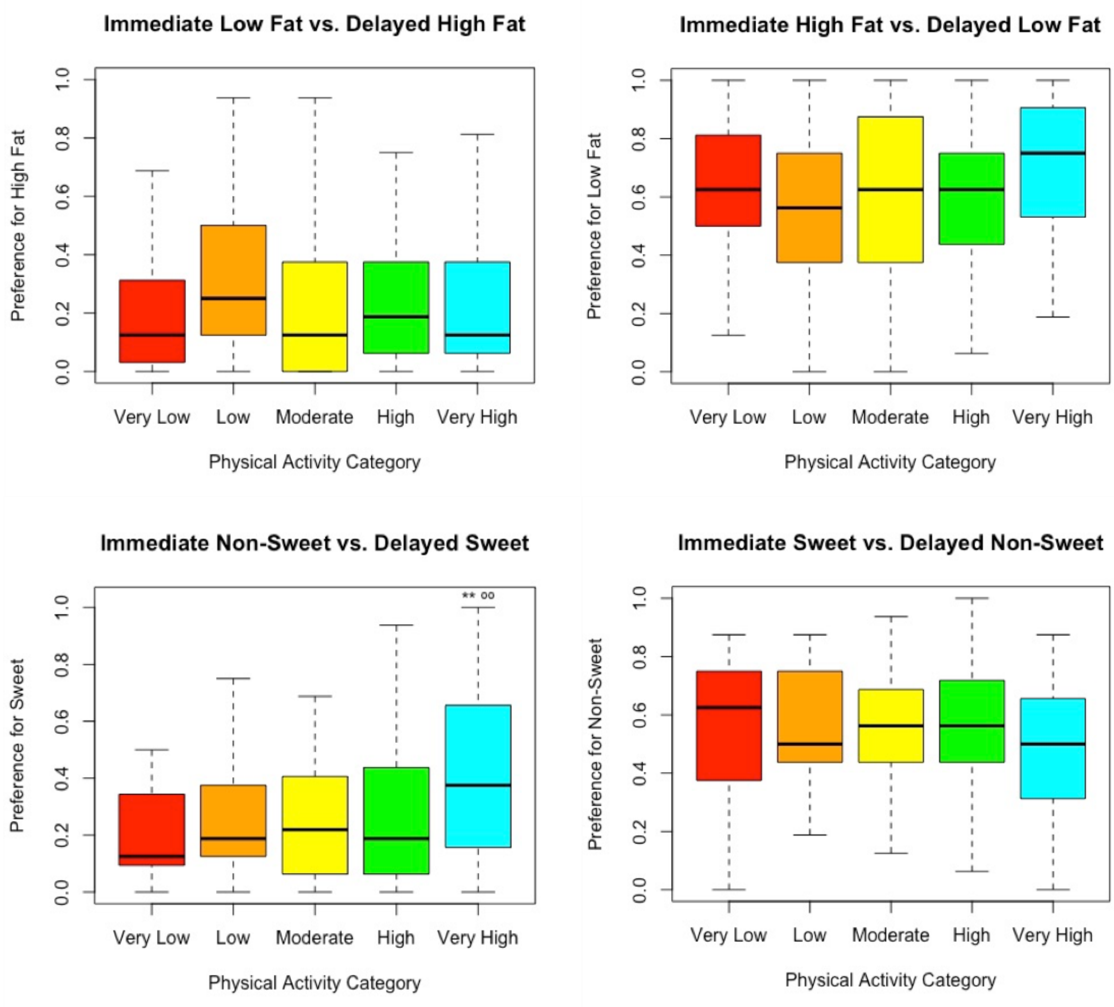

*Figure 4.8 Relative preference for high fat vs. low fat and sweet vs non-sweet foods between physical activity categories for immediate (0) vs. delayed (1) consumption (**p<0.01 when compared to moderately active participants, °°p<0.01 when compared to participants with very low physically activity levels)*

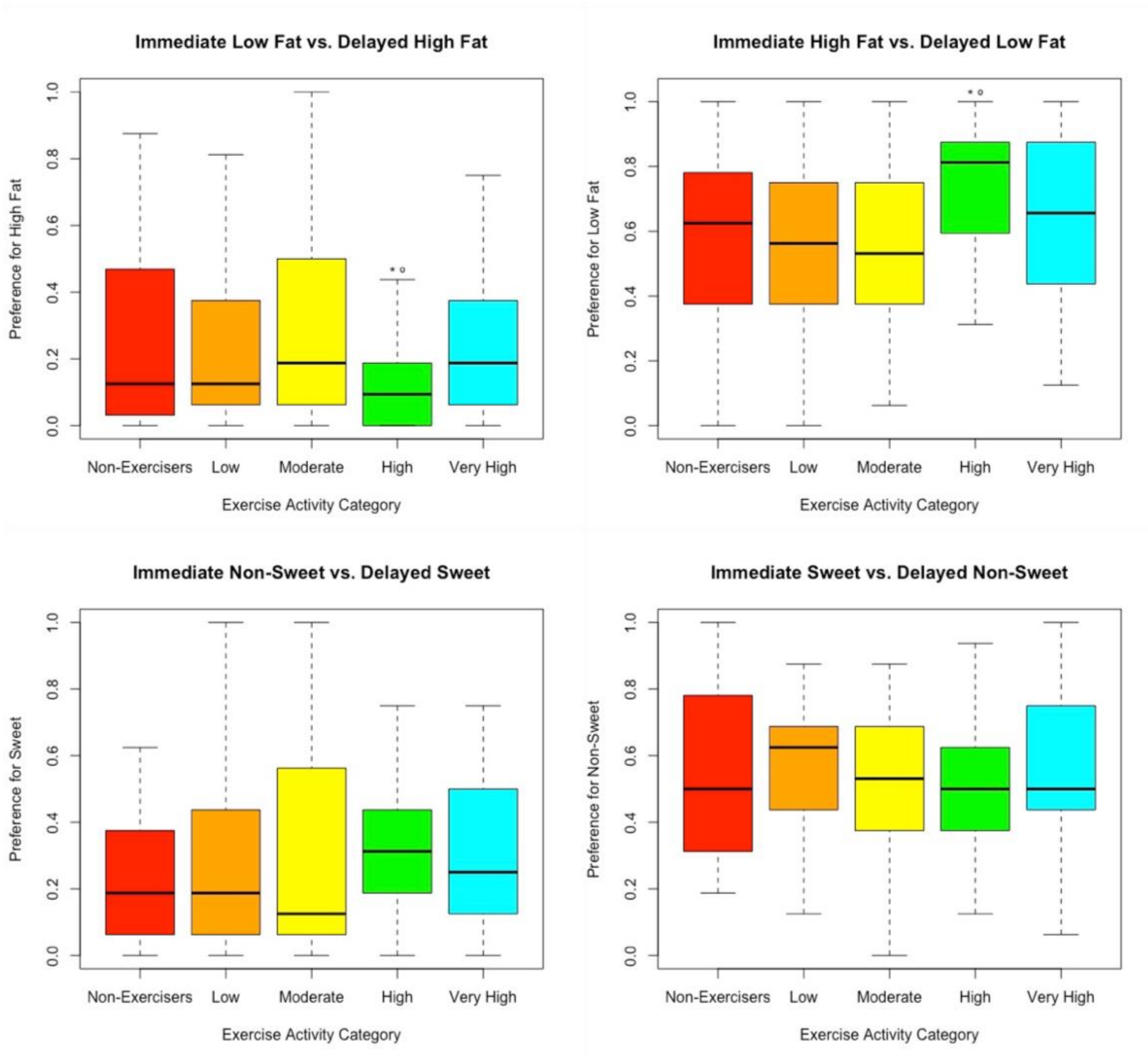

*Figure 4.9 Relative preference for high fat vs. low fat and sweet vs non-sweet foods between exercise activity categories for immediate (0) vs. delayed consumption (1) (*p<0.05 when compared to moderately active participants, °p<0.05 when compared to non-exercisers)*

When BMI was adjusted for PA, obese participants had a higher preference for sweet foods for delayed consumption over non-sweet foods for immediate consumption when compared to normal weight participants ($p=0.047$). Correspondingly, underweight participants had a lower preference for non-sweet foods for delayed consumption over sweet foods for immediate consumption when compared to normal weight participants, when BMI was adjusted for PA ($p<0.001$) and EX ($p<0.001$).

Time Preference

The time preferences for food consumption were assessed for of a standardized portion (3450 kcals) of each food type. Table 4.8 summarizes the mean time preferences for immediate over delayed food consumption. For overall, high fat, low fat, sweet and non-sweet choices participants tended to choose delayed options over one third of the time. Gender differences between immediate over delayed consumption were not statistically significant.

Table 4.8 Overall time preference of participants for each food type (mean ± SD).

Time Preference: Immediate vs. Delayed (0-1)	Total (n=174)	Female (n=137)	Male (n=37)
Low Fat	0.37 ± 0.19	0.37 ± 0.19	0.38 ± 0.16
High Fat	0.34 ± 0.18	0.34 ± 0.19	0.35 ± 0.14
Non-Sweet	0.40 ± 0.19	0.40 ± 0.19	0.43 ± 0.20
Sweet	0.41 ± 0.15	0.42 ± 0.15	0.39 ± 0.15
Overall	0.38 ± 0.15	0.38 ± 0.15	0.39 ± 0.13

Figures 4.10-4.12 show time preferences for food types according to PA and EX, respectively. Very highly active participants had a greater preference for delayed food consumption of high fat foods ($p=0.04$) and non-sweet foods ($p=0.049$) when compared

to very low activity participants. There were no significant differences between EX groups for time preference. However, when BMI was adjusted for PA, obese participants were found to have a higher preference for high fat foods for delayed consumption over immediate consumption compared to normal weight participants (p=0.03). Likewise, participants in the high risk WHR category had a higher preference for high fat foods for delayed consumption over immediate consumption when compared to low risk participants, when adjusted for both PA (p=0.01) and EX (p=0.02). Obese participants also had a higher preference non-sweet foods for delayed consumption over immediate consumption when adjusted for EX (p=0.04). Consistently, for overall time preference participants in the obese BMI category and high risk WHR category had a higher preference for delayed food options over immediate food options when analysis was adjusted for PA and EX (p=0.04 for all).

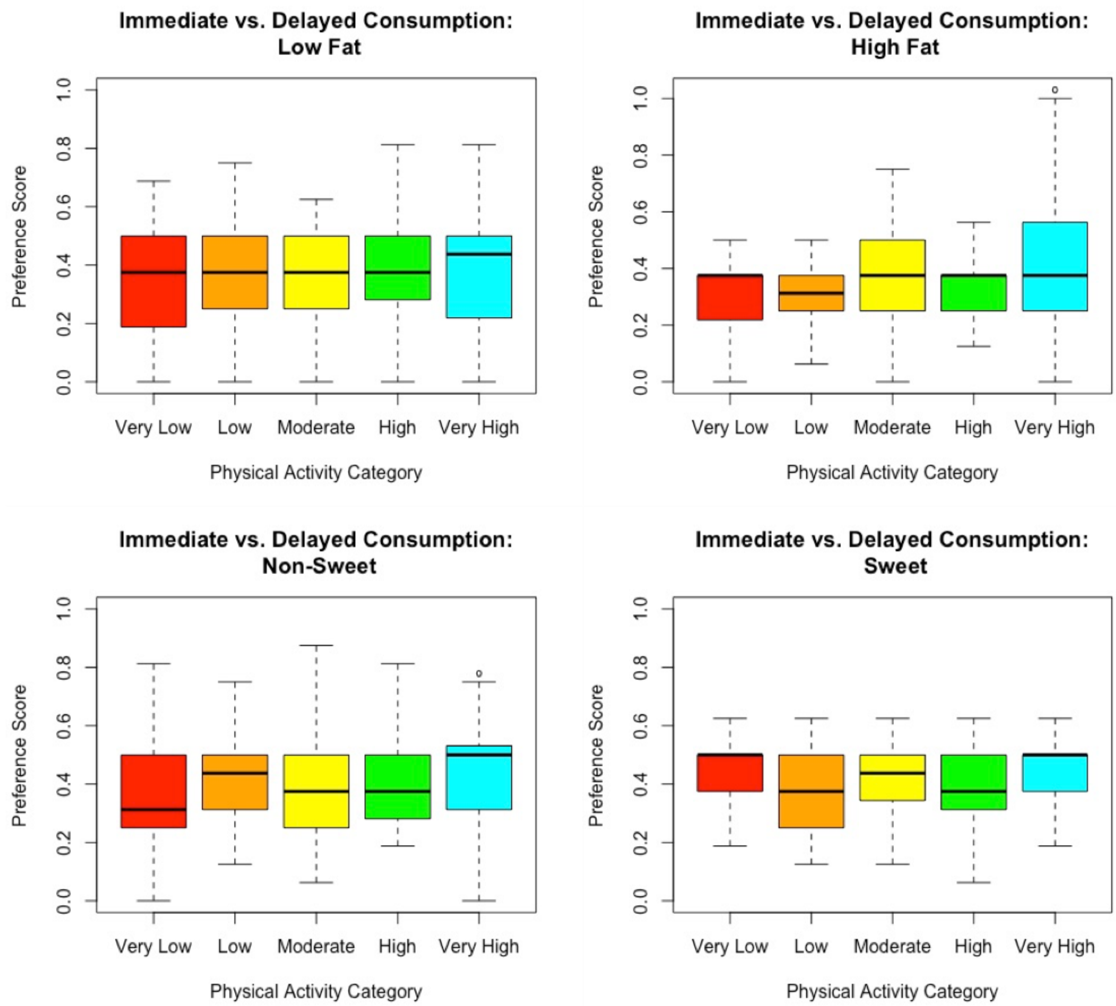

Figure 4.10 Relative time preference (0 – immediate; 1 – delayed) for food types based on physical activity categories (° p<0.05 when compared to participants with very low physically active levels).

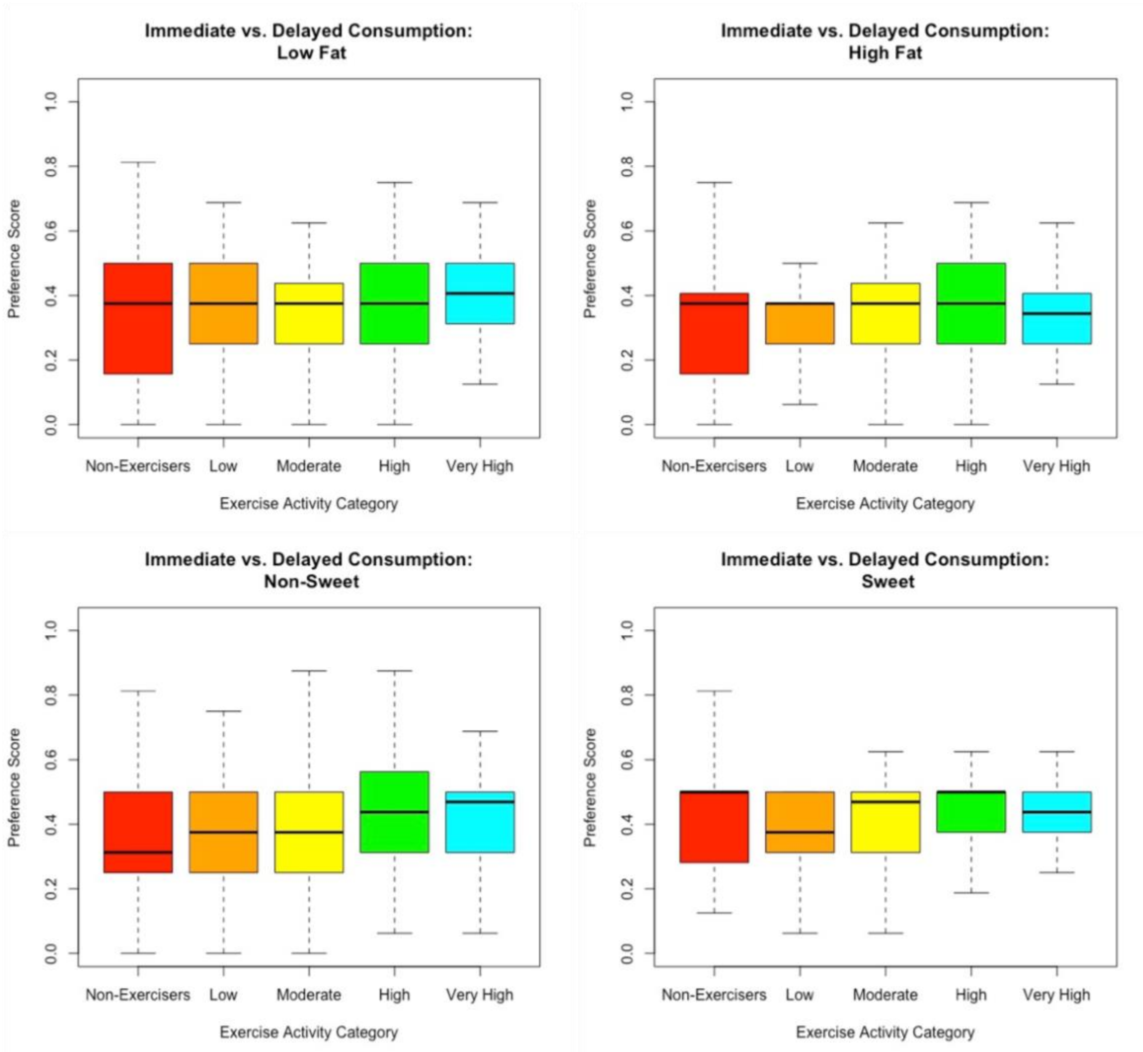

Figure 4.11 Relative time preference (0 – immediate; 1 – delayed) for food types based on exercise activity categories.

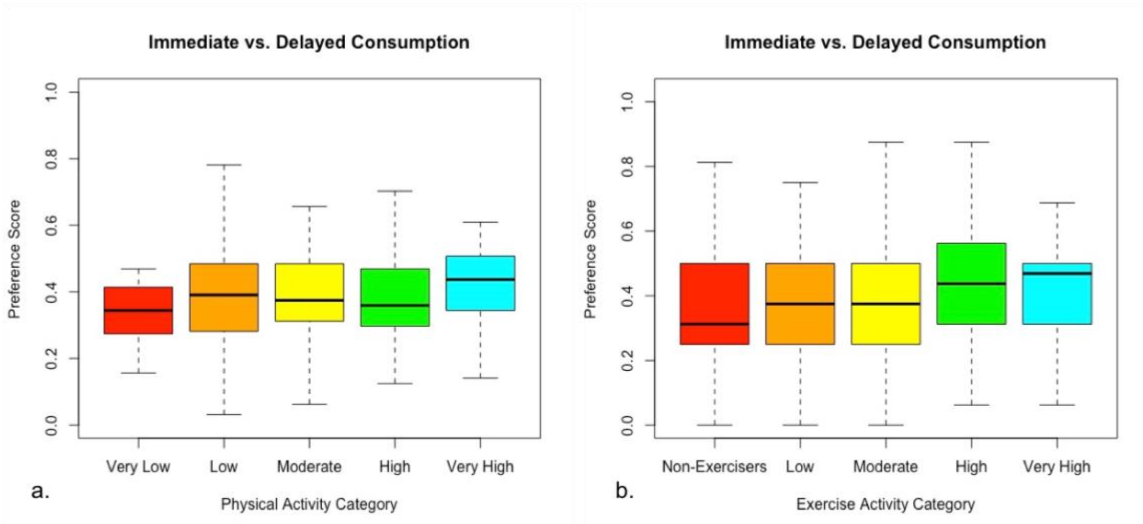

Figure 4.12 Overall time preference (0 – immediate; 1 – delayed) for any food type between a.) Physical activity and b.) Exercise activity categories for immediate and delayed consumption.

Amount Preference

Preferences for the ideal portion size of each food type were assessed separately for immediate and delayed consumption. Choices related to quantity data was collected for 70 participants. Quantities of each food type ranged from 75 to 450 kcals. Table 4.9 summarizes the mean amounts of food chosen for immediate and delayed consumption. On average, participants chose a portion of food equivalent to 225 – 300 kcals. Gender differences for the amount chosen for immediate and delayed consumption were not statistically significant. Also, there was a significant difference between the amount of high fat food chosen compared to the amount of low fat food chosen for both immediate and delayed consumption ($p<0.001$ for both).

Table 4.9 Average quantity of each food type chosen for immediately and delayed consumption.

Amount	Total (n=70)	Female (n=55)	Male (n=15)
Immediate			
Low Fat (kcal)	203 ± 61	198 ± 61	224 ± 57
High Fat (kcal)	296 ± 95[a]	300 ± 91	283 ± 112
Non-Sweet (kcal)	251 ± 73	252 ± 71	248 ± 84
Sweet (kcal)	248 ± 81	245 ± 80	259 ± 89
Delayed			
Low Fat (kcal)	217 ± 63	210 ± 63	243 ± 59
High Fat (kcal)	314 ± 83[a]	316 ± 80	308 ± 96
Non-Sweet (kcal)	263 ± 78	263 ± 77	264 ± 84
Sweet (kcal)	268 ± 69	264 ± 68	286 ± 70

[a] Difference from low amount (for both immediate and delayed consumption), p<0.001

Figures 4.13-4.16 show the average quantity chosen for each food type according to PA and EX. When PA was adjusted for BMI, those in the very physically active group were found to choose lower amounts of non-sweet food for later consumption ($p=0.047$) compared to moderately active individuals. Participants who exercised at high volumes chose higher quantities of low fat food for immediate and delayed consumption compared to those who exercise at a moderate level ($p=0.05$ & $p=0.006$, respectively) and non-exercisers ($p=0.03$ & $p=0.006$, respectively).

Obese participants were found to choose lower quantities of high fat food for immediate consumption when adjusted for both PA ($p=0.009$) and EX ($p=0.009$) when compared to those in the moderate activity groups. Correspondingly, obese participants also chose lower quantities of non-sweet foods for immediate consumption compared to normal weight participants for both PA ($p=0.017$) and EX ($p=0.026$).

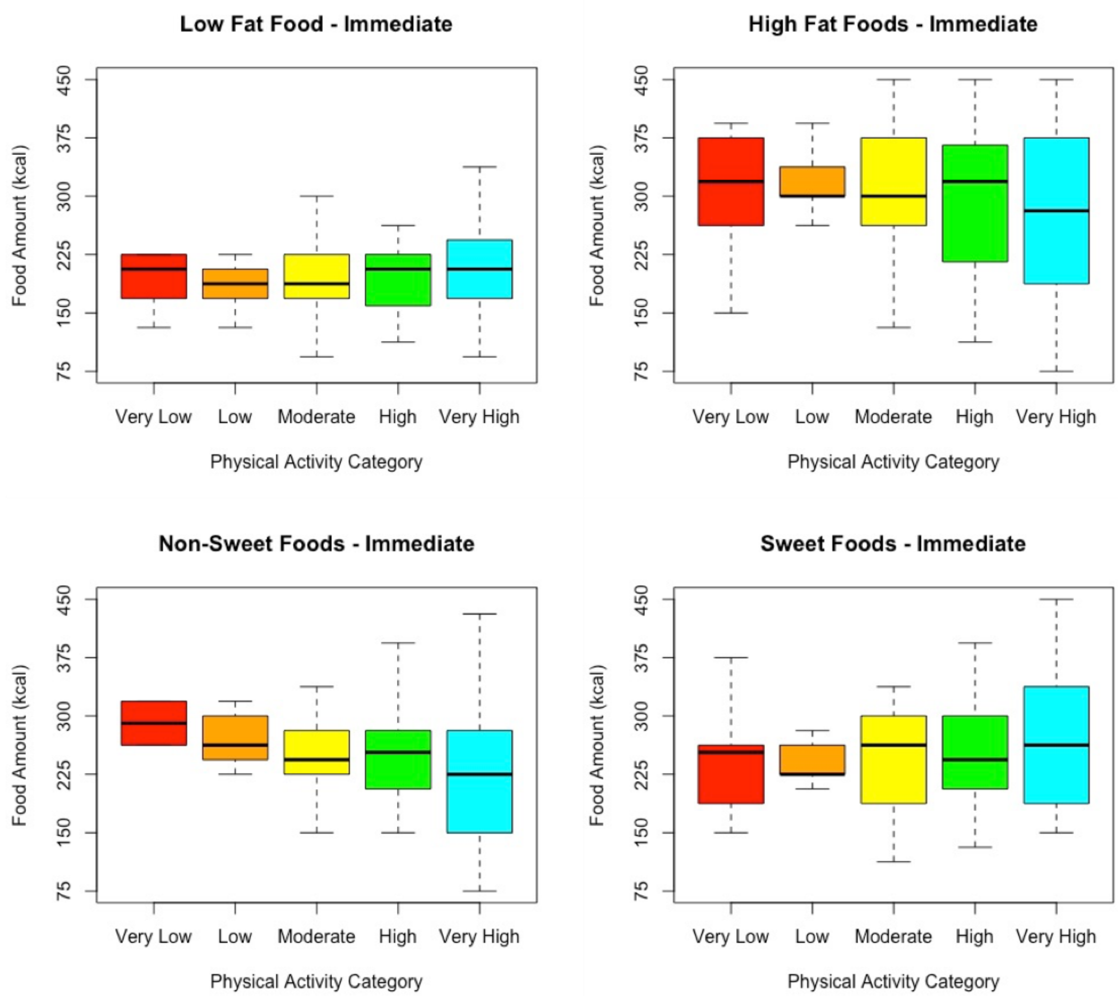

Figure 4.13 Average quantity chosen for each food type between physical activity categories for immediate consumption.

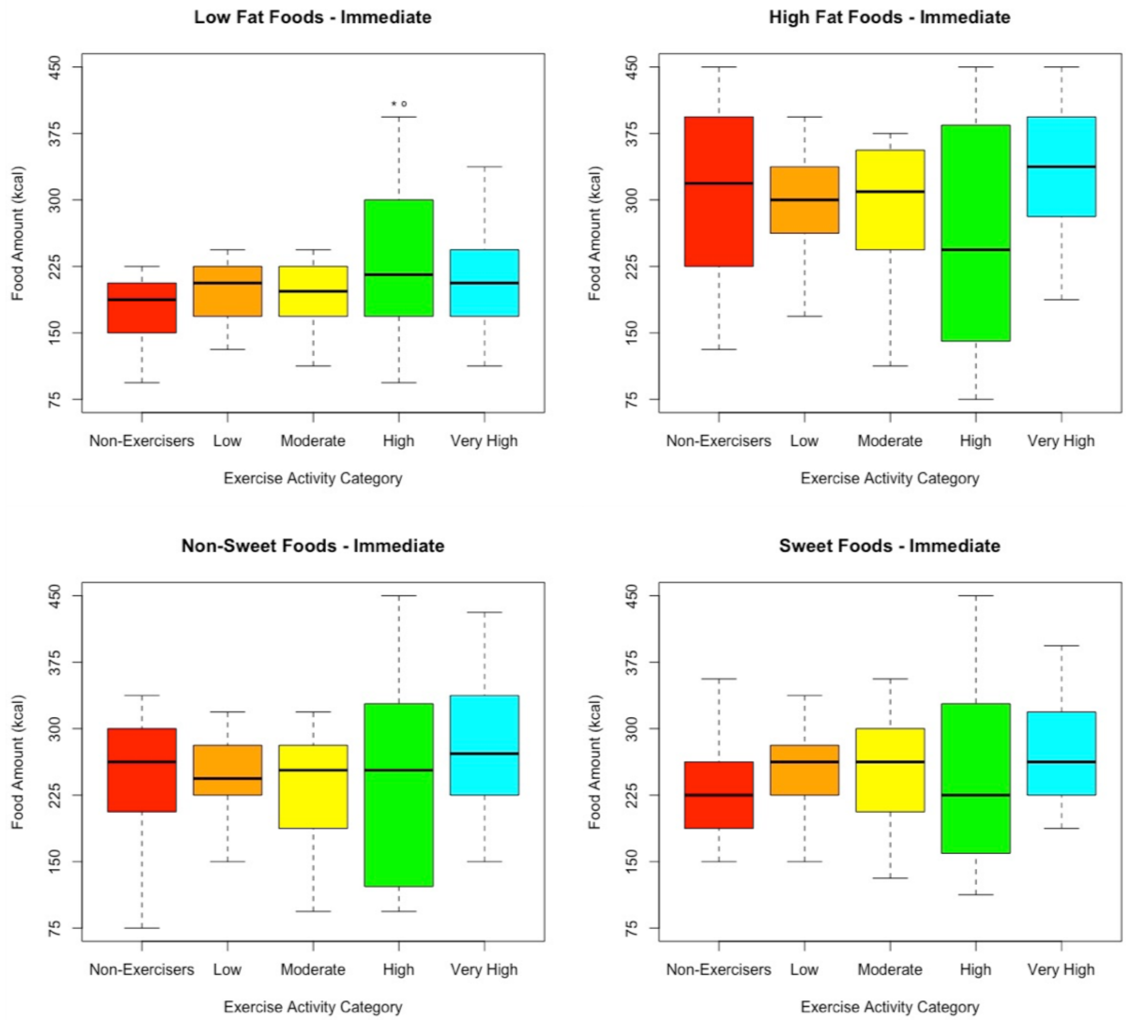

*Figure 4.14 Average quantity chosen for each food type between exercise activity categories for immediate consumption (*p<0.05 when compared to moderately active participants, °p<0.05 when compared to non-exercises).*

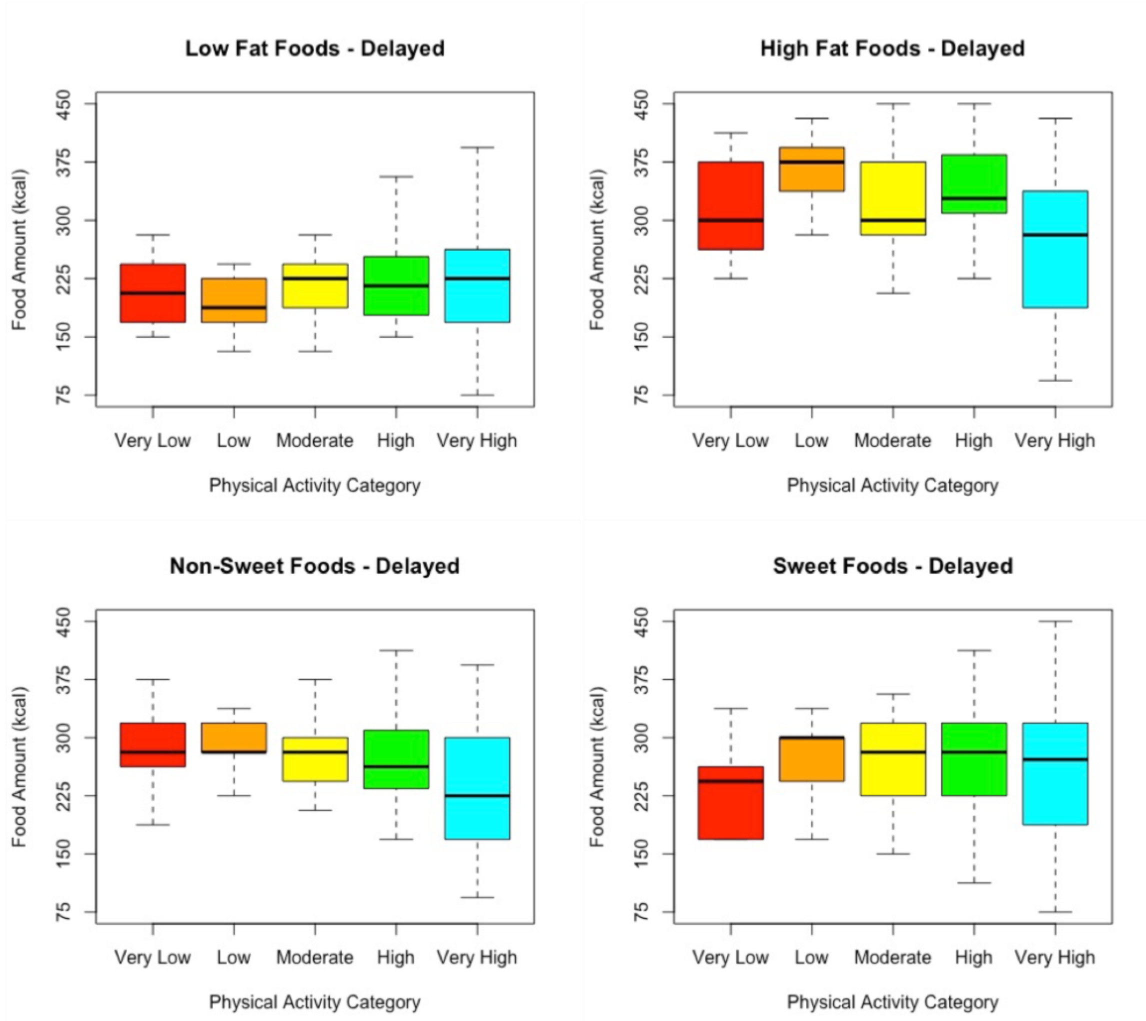

Figure 4.15 Average quantity chosen for each food type between physical activity categories for delayed consumption.

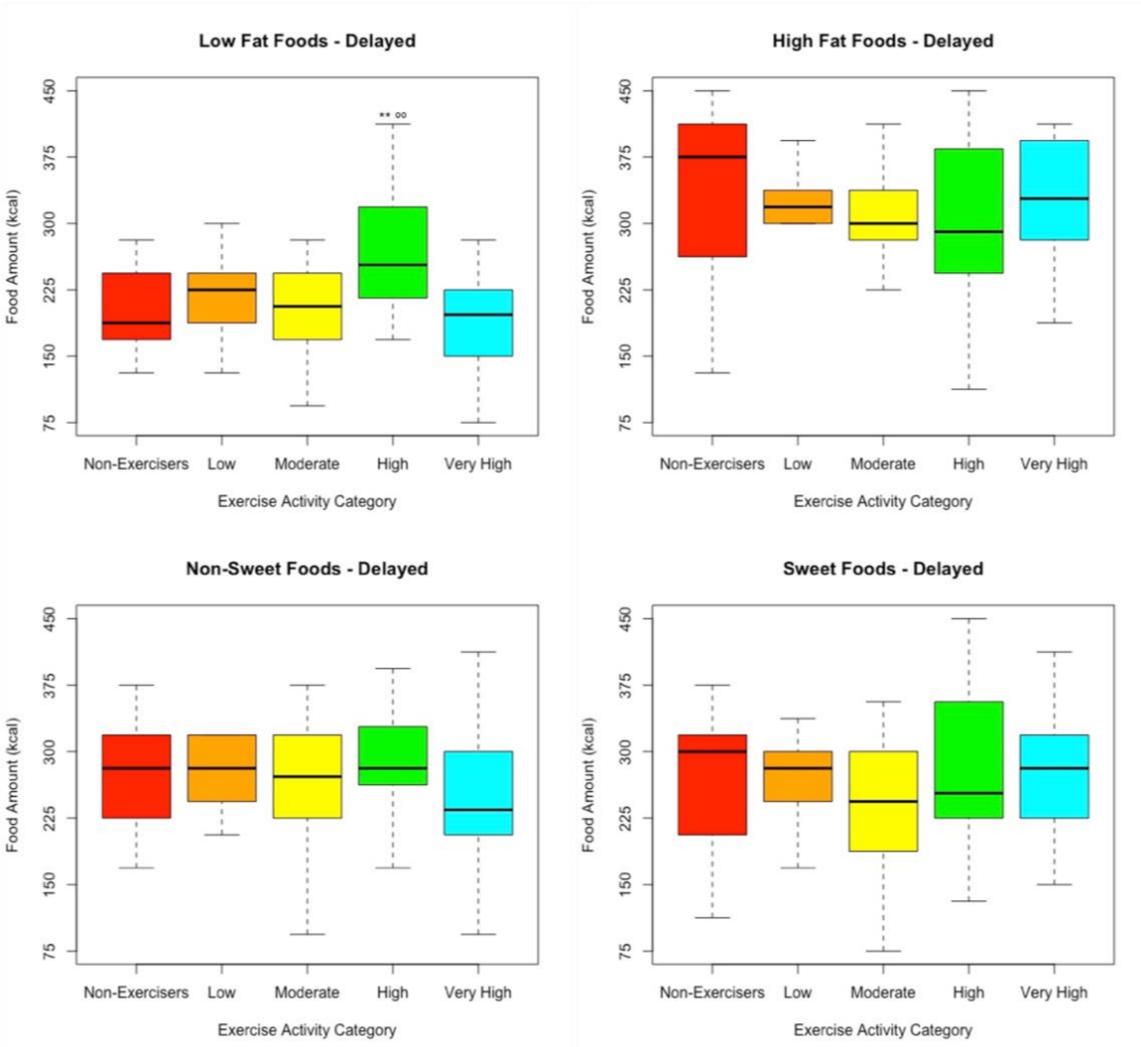

*Figure 4.16 Average quantity chosen for each food type between exercise activity categories for delayed consumption (**p<0.01 when compared to moderately active participants, °°p<0.01 when compared to non-exercises).*

Aim 3: Examine the relationship between physical activity/exercise and delayed discounting for decision making about money and food.

Food Discounting

Indifference points refer to the change in preference from smaller, sooner options to larger, later options or larger, later options to smaller, sooner options and were measured on a scale from 0-1. Participants' indifference points for changes in quantity and time preference are shown in Table 4.10. For all food types, participants in study sample 1 (0-750 kcals; collected in the fall semester) chose larger, later options 40-44% of the time. Participants in study sample 2 (0-450 kcals; collected in the spring semester) chose larger, later options for high fat foods 53% of the time and non-sweet and sweet foods just under half of the time. For low fat foods, study sample 2 participants chose low fat options 39% of the time. There were no statistically significant gender differences seen between mean food indifference points (Table 4.10). However, there were statistically significant differences between means for low fat and high fat indifference points for both study sample 1 ($p<0.001$) and study sample 2 ($p<0.001$) (Table 4.10).

Table 4.10 Food indifference points of participants who switched from smaller, sooner options to larger, later options (mean ± SD).

Indifference Point	Total	Females	Males
Study sample 1 (n=104)			
Low Fat	0.40 ± 0.19	0.38 ± 0.19	0.48 ± 0.20
High Fat	0.44 ± 0.18[a]	0.42 ± 0.18	0.52 ± 0.17
Non-Sweet	0.41 ± 0.20	0.39 ± 0.19	0.47 ± 0.21
Sweet	0.43 ± 0.19	0.41 ± 0.19	0.50 ± 0.18
Study sample 2 (n=70)			
Low Fat	0.39 ± 0.17	0.38 ± 0.16	0.46 ± 0.20
High Fat	0.53 ± 0.15[a]	0.51 ± 0.15	0.60 ± 0.15
Non-Sweet	0.47 ± 0.15	0.45 ± 0.14	0.57 ± 0.17
Sweet	0.49 ± 0.18	0.47 ± 0.17	0.60 ± 0.19

[a] different from low fat, $p<0.001$

Study sample 1: Figures 4.17 and 4.18 show the food indifference points of participants who switched from smaller, sooner options to larger, later options for each food type according to PA and EX for study sample 1. Participants in the high PA group had a greater preference for larger, later options for high fat (p=0.008), non-sweet (p=0.006) and sweet (p=0.04) foods compared to those in the very low PA group. When PA was adjusted for gender, participants in the low activity group also had a higher preference for larger, later options of non-sweet foods (p=0.04) compared to participants in the very low activity group. Additionally, when BMI was adjusted for PA, underweight participants were found to have a lower preference for larger, later options of sweet foods (p=0.03) compared to normal weight participants.

When EX was adjusted for BMI, compared to non-exercisers, participants in the moderate activity group were found to have a greater preference for larger later options of all food types (high fat: p=0.04, low fat: p=0.008, sweet: p=0.01, non-sweet: p= 0.01). Additionally, when EX was adjusted for BMI, those in the high exercise group were found to have a greater preference for larger, later options of low fat (p=0.03) and non-sweet (p=0.02) foods, while those in the very high activity group had a greater preference for high fat (p=0.03) and low fat (p=0.047) foods compared to non-exercisers. When BMI was adjusted for EX, overweight participants were found to have a lower preference for larger, later options of low fat (p=0.009), sweet (p=0.008) and non-sweet (p=0.01) food compared to normal weight participants.

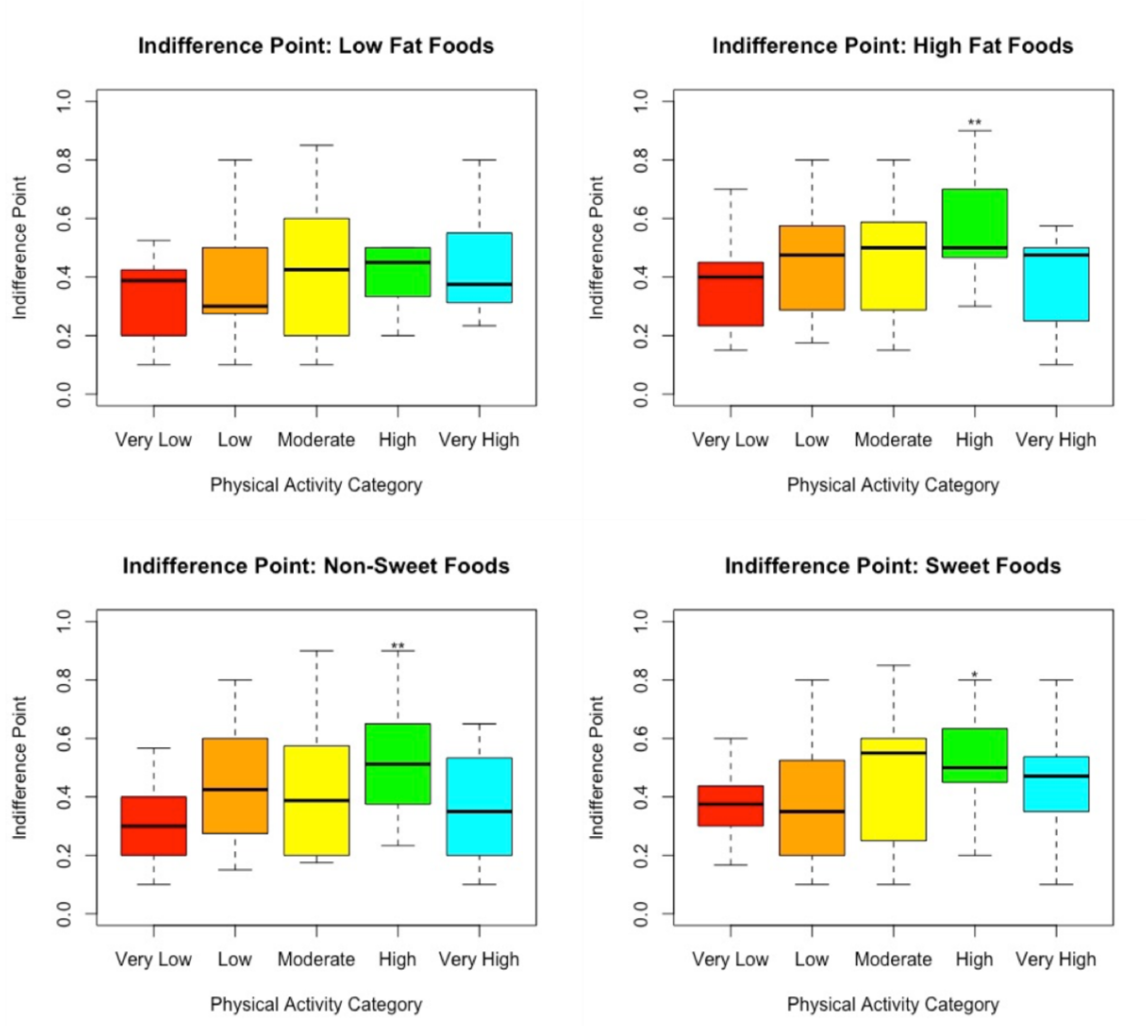

*Figure 4.17 Food indifference points of participants who switched from smaller, sooner options (0) to larger, later options (1) for each food type between physical activity categories for study sample 1 (*p<0.05 & **p<0.01 when compared to very low activity participants).*

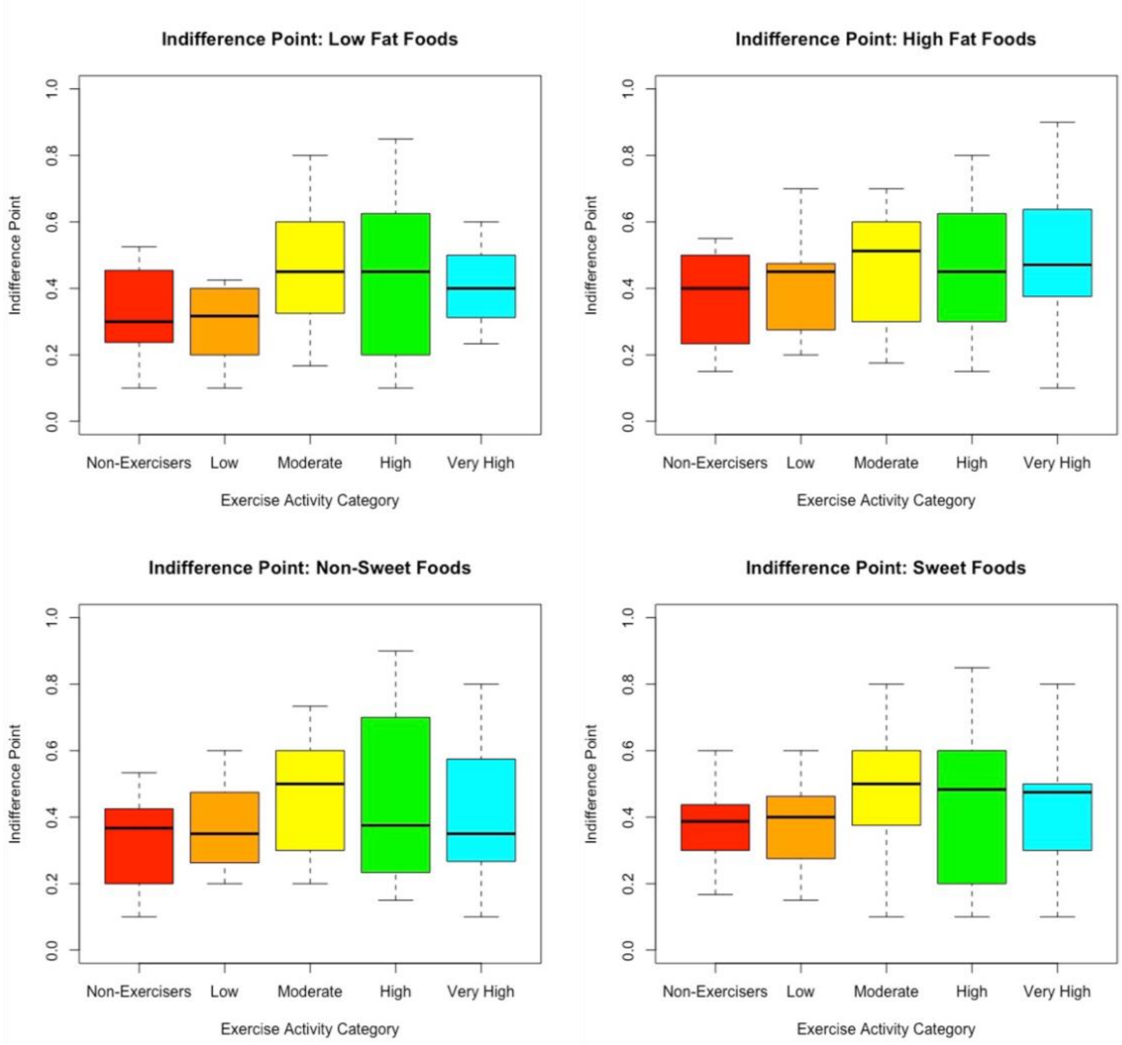

Figure 4.18 Food indifference points of participants who switched from smaller, sooner options (0) to larger, later options (1) for each food type between exercise activity categories for study sample 1.

Study Sample 2: Figures 4.19 and 4.20 illustrate the food indifference points of participants who switched from smaller, sooner options to larger, later options for each food type according to PA and EX for study sample 2. There were no statistically significant differences between PA or EX groups for the means of any of the food indifference points. However, males were found to have a greater preference than females for larger, later options of non-sweet foods ($p=0.02$), when gender was adjusted for PA. Additionally, when gender was adjusted for EX, male participants had a greater preference for sweet ($p=0.04$) and non-sweet ($p=0.046$) foods compared to female participants.

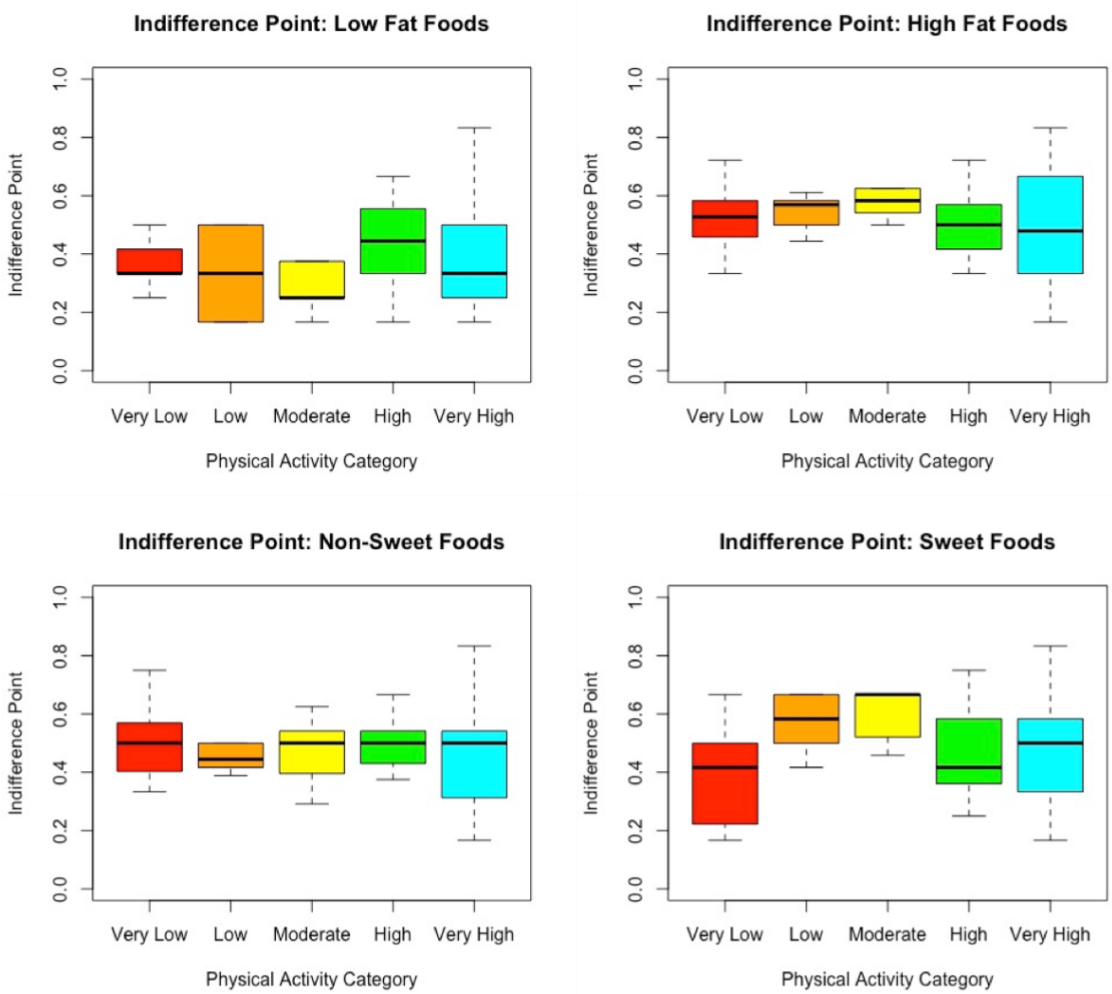

Figure 4.19 Food indifference points of participants who switched from smaller, sooner options (0) to larger, later options (1) for each food type between exercise activity categories for study sample 2.

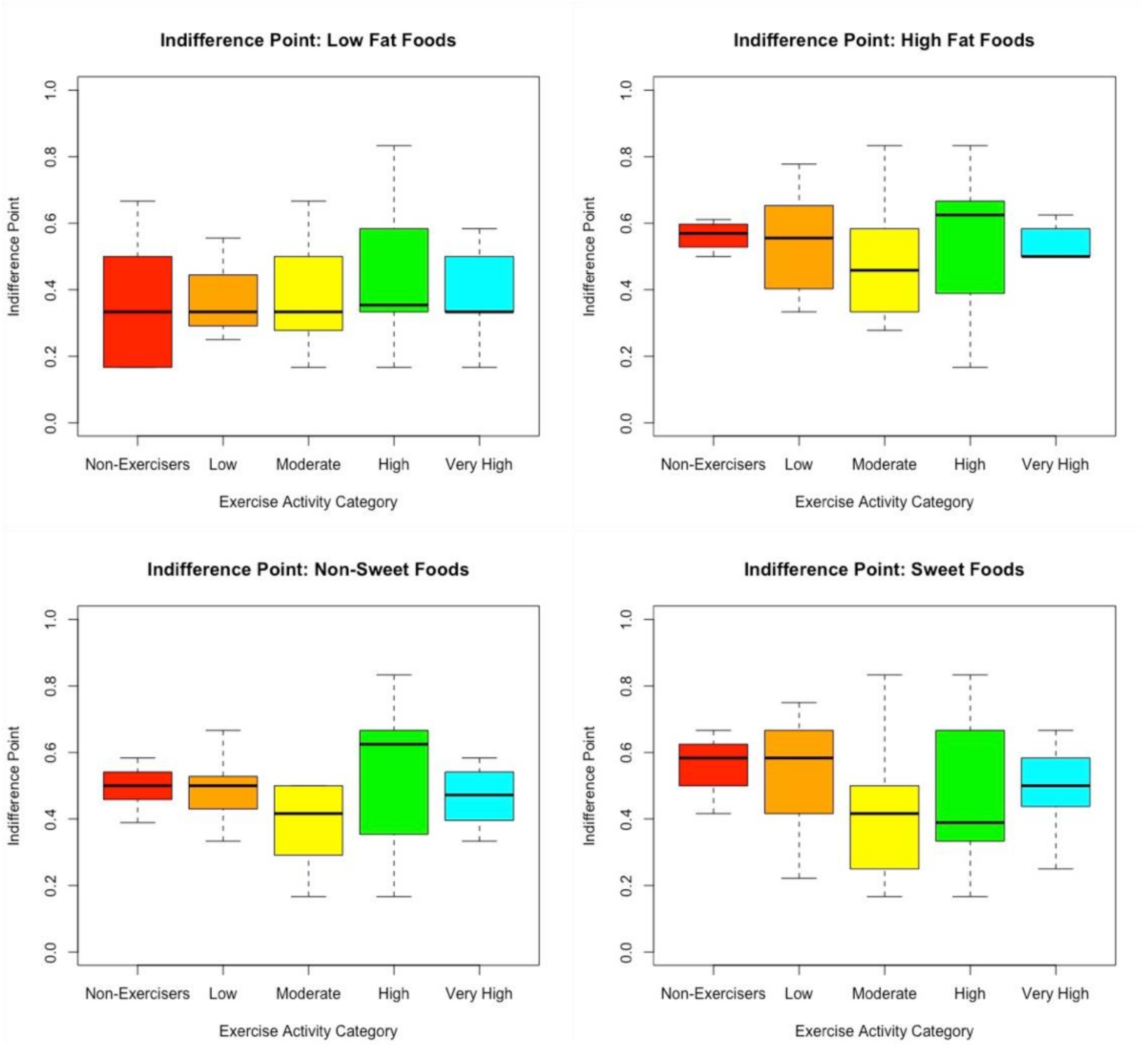

Figure 4.20 Food indifference points of participants who switched from smaller, sooner options to larger, later options for each food type between exercise activity categories for study sample 2.

Money Discounting

The mean indifference point and discounting rate for money of the participants are shown in Table 4.11. Participants' preferred to receive smaller, sooner options over larger, later options demonstrated by an area under the curve of approximately 40%. Gender differences for the money indifference point and discount rate were not statistically significant.

Table 4.11 Money indifference point for participants who switched from smaller, sooner amounts to later, later amounts and discounting rate (mean ± SD).

Money	**Total**	**Female**	**Male**
Area Under the Curve	0.40 ± 0.25	0.39 ± 0.24	0.42 ± 0.27

Area under the curve (AUC) is a simple method to summarize indifference points and provides a single number to describe how much devaluation is caused by time delay (Odum, 2011). The AUC ranges from 0 to 1, with a larger AUC representing less delayed discounting (Odum, 2011). Figure 4.21 depicts the AUC for money according to PA and EX groups. There were no statistically significant differences between PA or EX groups based on means discounting rates. Figure 4.22 shows the correlation coefficients between money AUC and indifference points for all food types. For study samples 1 and 2, AUC for money were only weakly correlated with of the food indifference points (all $p>0.05$).

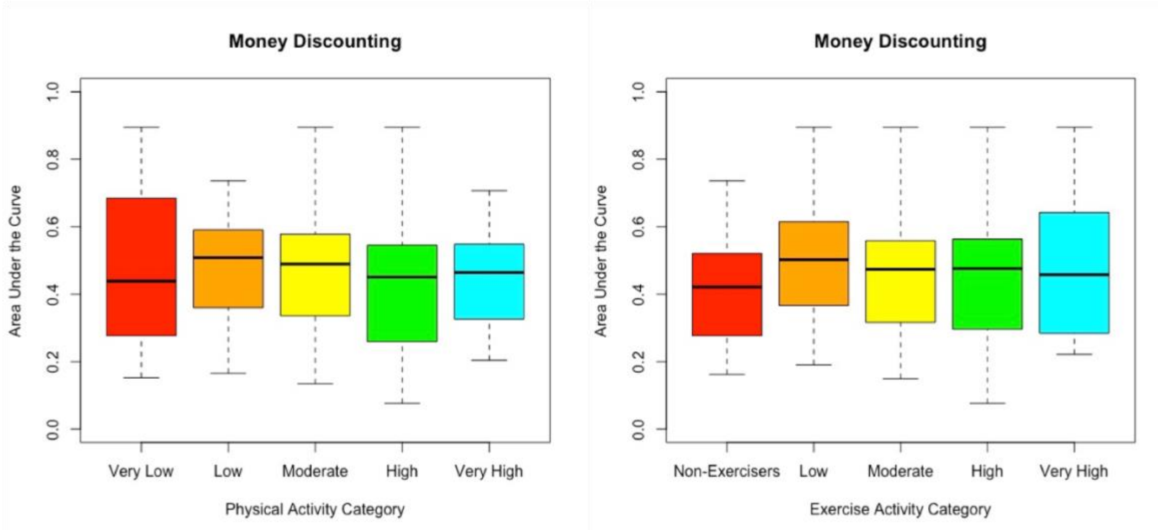

Figure 4.21 Average money discount rates of participants according to physical activity and exercise groups.

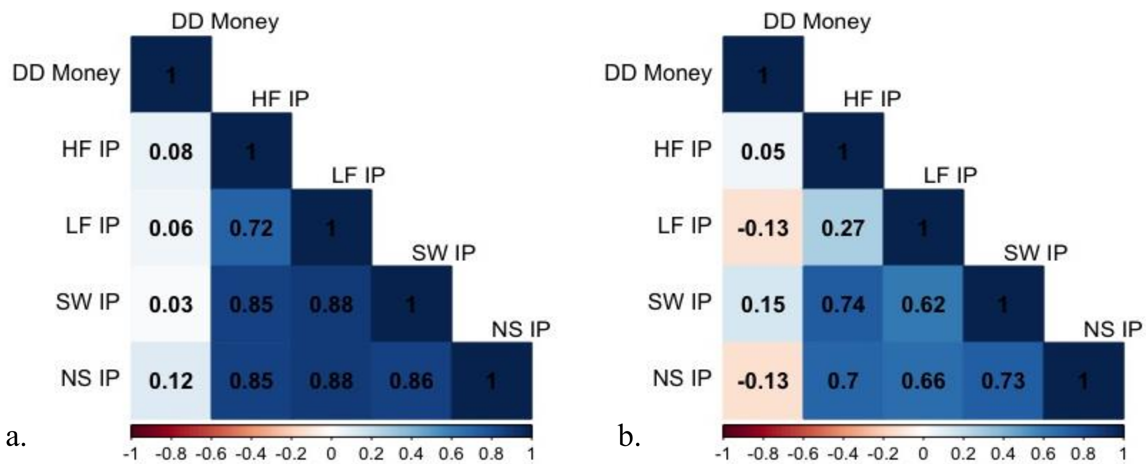

Figure 4.22 Correlation between indifference points (IP) for different food types and delayed discounting rate (DD) for money for a. Study Sample 1 (n=104) and b. Study Sample 2 (n=70). Legend: HF = High Fat, LF = Low Fat, SW = Sweet, NS = Non-Sweet.

CHAPTER 5. DISCUSSION

This study examined the relationship between habitual physical activity (PA), exercise and food choices. Collectively, the results suggest that although moderately correlated, PA and exercise exert differential effects on food choices. Participants who were engaged in higher levels of PA were consistently more likely to choose sweet foods for immediate and delayed consumption. Whereas, individuals who exercised at higher volumes had greater liking and preference for low fat foods. No statistically significant relationship was found between discounting for money and habitual PA or exercise, suggesting that choices between food options are more sensitive to detect differences in decision making about food related to activity and exercise.

The Influence of Habitual Physical Activity and Exercise on Food Preference

Overall, all participants had a greater tendency to choose low fat and non-sweet food (65-72%) over high fat and sweet foods, independent of whether the food items were offered immediately or with a time delay. Specifically, participants who reported being habitually engaged in high volumes of exercise were 14-18% more likely to prefer low fat foods when compared to non-exercisers. These results revealed a skewed relationship towards high volume exercisers having a greater preference for low fat food and did not support the hypothesized curvilinear relationship according to which inactive participants and highly active participants would have a greater tendency to choose highly palatable foods (high fat and sweet) when compared to moderately active individuals. Previous studies support our findings. Panek et al. (2014) investigated the effect of 2 weeks of aerobic exercise on the reinforcing value of high energy density

(HED) and low energy density (LED) foods, a paradigm that mirrored our use of high fat (HED) and low fat (LED) foods. The authors reported a dose-related response for exercise on the reinforcing value of food (Panek, Jones, & Temple, 2014). Consistent with our findings for high volume exercisers versus non-exercisers, exercise increased the reinforcing value of LED foods with a concomitant reduction in the reinforcing of value HED foods, and this effect was more pronounced in individuals who exercise 5 days per week when compared to 3 days per week and non-exercise controls (Panek et al., 2014).

Similarly, Crabtree et al. (2014) demonstrated that acute bouts of high-intensity aerobic exercise induced a greater reaction in the brain's reward-related neural systems to visual cues of LED foods, whereas the response to cues of HED foods was reduced by exercise. Additionally, a randomized crossover study reported that a single bout of exercise decreased the preference for high fat relative to low fat food in exercisers but not in non-exercising controls (McNeil et al., 2015). Since exercise is known to reduce responsiveness in food reward regions of the brain post-exercise (Evero, Hackett, Clark, Phelan, & Hagobian, 2012), this finding suggests that low fat foods may be preferred by exercisers. This may be due to nutritional recommendations for exercise emphasizing less fat intake and the greater intake of carbohydrates and proteins (Thomas, Erdman, & Burke, 2016), as well as the assumption that LED foods only moderately impact homeostatic mechanisms compared to HED foods (Graham Finlayson, King, & Blundell, 2007). Combined, these findings suggest that the rewarding value of low fat and high fat foods in inactive individuals may be altered when they become more active.

To our knowledge, no studies have examined the specific effect of physical activity on food preference (frequency of choice). However, we observed that habitual participation in high levels of PA was associated with a 13-16% higher chance of preferring sweet over non-sweet foods when compared to individuals who engaged in very low levels of physical activity. Interestingly, when accounting for BMI, both underweight and obese participants had a higher preference for sweet food over non-sweet food when compared to normal weight participants. Additionally, underweight participants also had a greater preference for high fat foods.

Overall, exercise seems to elicit a greater response to energy-dense foods, whereas physical activity seems to be associated with highly palatable, sweet foods. This suggests that those who participate in high volumes of exercise activity may make changes to their behavior which potentially decreases the rewarding value of high fat foods and increases the value of low fat foods/high carbohydrate foods.

Relationship between Habitual Physical Activity and Food Liking

In general, all participants had a greater liking for low fat and non-sweet foods, rating these 2 food categories on average 7-9% higher than high fat and sweet foods. Yet, further analysis revealed a significantly greater liking for low fat foods among those who exercised at high volumes, with high volume exercisers rating low fat foods 8-13% higher than non-exercisers. Support for this finding was found in a study conducted by McNeil et al. (2014), who noted that liking for high fat foods decreased following an acute bout of exercise resistance. Interestingly, a decrease in liking was not observed following a bout of aerobic exercise, suggesting that exercise type may also influence response to food reward. Additionally, consistent with the current findings, there was no difference in liking for sweet over non-sweet foods between exercisers and non-exercisers (McNeil et al., 2015). This suggests that exercise may reduce activity in liking specific regions of the brain when compared to sedentary activity (Evero et al., 2012). However, the effect of exercise on food liking remains inconclusive, as other studies have reported no support for changes influenced by exercise (Farah, Brunstrom, & Gill, 2012; Finlayson, Bryant, Blundell, & King, 2009; Panek et al., 2014).

Interestingly, habitual PA did not impact food liking. In support of our finding, previous studies have reported no differences in liking for high fat or low fat foods between healthy, non-obese participants with different PA levels (Beaulieu, Hopkins, Blundell, & Finlayson, 2017; Beaulieu, Hopkins, Long, Blundell, & Finlayson, 2017). Similar to our study, which required participants to abstain from eating for at least 3 hours prior to participation, participants in the previous studies were tested for hedonic food reward response 3-4 hours after consuming breakfast and were also tested after lunch (Beaulieu, Hopkins, Blundell, et al., 2017; Beaulieu, Hopkins, Long, et al., 2017). Another noteworthy finding of the two studies was that the high energy preload (a liquid with a specific macronutrient make up given before a meal to examine the effects of a food attribute on subsequent intake) and satiety suppressed liking for high fat foods to a greater extent than the low energy preload and hunger across all PA levels (Beaulieu, Hopkins, Blundell, et al., 2017; Beaulieu, Hopkins, Long, et al., 2017). Moreover, Horner et al. (2016) found no difference in liking between habitually active and inactive men in the fasted state, but liking for high fat and sweet foods were significantly lower in active men in the fed state. Additionally, a more rapid rate of gastric emptying was shown to be associated with increased liking for non-sweet foods (Horner, Finlayson, Byrne, & King, 2016). Therefore, higher sensitivity to homeostatic cues may have a greater impact on food liking than energy density in active compared to inactive individuals (Beaulieu, Hopkins, Long, et al., 2017; Horner et al., 2016).

Impact of Exercise on Hypothetical Food Amounts

Participants generally tended to choose moderate portions of food for both immediate and delayed consumption. Physically active participants had a greater tendency to choose smaller portions of non-sweet food, whereas those participants who exercised at high volumes chose larger portions of low fat food more frequently when compared to moderately active participants. Additionally, obese participants had a greater preference for smaller portions of high fat and non-sweet foods. Previous evidence suggests that there exists a curvilinear relationship between habitual physical activity and energy intake (Beaulieu, Hopkins, Blundell, & Finlayson, 2016; Blundell, 2011; Blundell et al., 2015). However, this relationship was not apparent from the current study, despite each food portion corresponding to an increasing amount of calories (75-450 kcals). In this study however we demonstrated that physical activity vs. exercise, BMI and food type can affect hypothetical choices for portion size (Panek et al., 2014).

Most studies have focused on the impact of exercise on food intake. In general, exercise may suppress appetite, anticipation and ad libitum consumption of food along with decrease responsiveness to food cues in food reward brain regions (Evero et al., 2012; Fearnbach et al., 2016). Responsiveness to food and the rewarding value of food may interact with appetite regulating hormones to affect food intake (Cornier, Melanson, Salzberg, Bechtell, & Tregellas, 2012; Evero et al., 2012; Fearnbach et al., 2016). To our knowledge, only one study also utilized a computer-based approach to examine the effect of acute exercise on hypothetical portion size (Farah et al., 2012). A single bout of moderate exercise was shown to decrease hunger and portion size (Farah et al., 2012). When given the opportunity to choose their ideal portion size, participants chose smaller portion following the exercise condition when compared to the rest condition (Farah et al., 2012). Interestingly, ideal portion size was also reported to be positively associated with food liking (Farah et al., 2012; Finlayson et al., 2007). Although not directly examined, the results of our current study are supportive of this relationship since exercisers both liked and chose larger portions of low fat foods.

Time Preference for Food and Delayed Discounting for Food and Money

Overall, participants demonstrated a strong tendency to choose immediate over delayed food options. In addition, very physically active participants had a greater preference for high fat and non-sweet foods when asked for delayed consumption. These results were reflective of our finding for food indifference points, which represent the point at which the tradeoff between smaller, sooner options is equally appealing to larger, later options. Although a discounting rate, which is typically used to quantify delayed gratification when utilizing monetary choices, could not be determined for food choices, switching to larger, delayed options at an earlier point when given decreasing amounts of immediate food may be indicative of more future orientation whereas switching later along the continuum to larger delayed may be associated with greater preference for immediate reward. High levels of PA and exercise seemed to be associated with reduced future discounting of food when compared to inactive participants, implying that highly active participants were willing to delay gratification for food. To our knowledge, there is no literature on the association between time preference for food or food discounting with physical activity or exercise. However, this study supports the importance of physical activity and exercise as a tool to reduce future discounting.

Surprisingly, when looking at time preference for a similar quantity of food (Figure 3.3: Right now vs. next meal), obese participants and those with a high WHR demonstrated a greater preference for delayed food options overall and specifically for high fat and non-sweet foods. In contrast, when visual food cues were presented in decreasing amounts was juxtaposed to a maximal amount of food at a later time (Figure 3.4), obese participants had a greater tendency to choose immediate satisfaction over delayed satisfaction, indicating a higher discounting of food when compared to normal weight individuals. Additionally, underweight participants had a greater tendency to choose immediate gratification for sweet food. Higher rates of discounting of future food rewards over time have been shown to be associated with obesity (Amlung et al., 2016; Barlow, Reeves, McKee, Galea, & Stuckler, 2016; Ely et al., 2015; Epstein, Salvy, Carr, Dearing, & Bickel, 2010; Weller, Cook, Avsar, & Cox, 2008) and higher body fat percentages (Hendrickson, Rasmussen, & Lawyer, 2015; Rasmussen, Lawyer, & Reilly, 2010). Additionally, food has a higher reinforcing value on overweight/obese compared to lean individuals (Epstein et al., 2010). Research also suggests that food discount may be more easily attenuated than money discounting by interventions such as mindful eating (Hendrickson & Rasmussen, 2013) and physical activity (Sofis et al., 2017).

Physical activity has been shown to decrease discounting by improving brain function, reducing impulsivity which decreases the occurrences of risky behaviors (e.g. substance abuse) (Sofis et al., 2017). Physical activity has also been shown to strengthen and reinforce other forms of interventions geared to promoting weight loss (e.g. mindful eating) (Sofis et al., 2017). Sofi et al. (2017) demonstrated the rate of delayed discounting for money was attenuated by physical activity and continued to be reduced as a physically active lifestyle was maintained. The authors speculated that adherence to the experimental protocol and improvements to cardiorespiratory fitness both potentially influenced the observed reductions in delayed discounting (Sofis et al., 2017). In contrast, the current study did not detect differences in delayed discounting for money across the PA or exercise groups. Participants in the current study were younger and there is evidence to suggest that older individuals tend to discount future outcomes at a lower rate than younger individuals (Löckenhoff, O'Donoghue, & Dunning, 2011), which may help to account for the dissimilarity in results.

Limitations

Though our study was able to assess a differential relationship between physical activity and exercise on food choice parameters, there were some limitations. Most studies conducted in the United States examined the dietary habits such as energy intake or healthy vs. unhealthy foods or eating habits, but there is limited data on food preferences for fat and sweet preferences. As such, we used the Leeds Food Preference Questionnaire (LFPQ) (Finlayson, King, & Blundell, 2008) and adapted the questionnaire with foods that would be more suitable for an American population. We further included a measure of time preference. Although the validity of this modified questionnaire was not established, the LFPQ has been validated for European and Arab populations (Alkahtani, Dalton, Abuzaid, Obeid, & Finlayson, 2016; Griffioen-Roose, Finlayson, Mars, Blundell, & De Graaf, 2010; Verschoor, Finlayson, Blundell, Markus, & King, 2010). Moreover, Farah et al. (2012) demonstrated that computer based assessments may be useful tools for determination of the effects of exercise on hedonic factors associated with decisions made about food.

Actual food choices were not presented due to practical restrictions in providing all food options. Instead, visual cues were provided to elicit the perception of pleasure to assist with the decision making process (Finlayson et al., 2007). The use of hypothetical over actual decisions may be a limitation, as it is often perceived that hypothetical choices may not translate to real world decisions. However, research has shown that hypothetical monetary (Locey, Jones, & Rachlin, 2011) and food (Robertson & Rasmussen, 2018) choices can be as valid as actual choices. Moreover, considering the difficulties in quantifying food intake for research purposes largely due to misreporting errors, hypothetical portion size may be a useful assessments because it has been shown to be closely relate to actual portion size (Farah et al., 2012).

Additionally, the use of self-reported PA data presents another limitation. While self-reported PA data has been shown to both over- and under-report directly measured PA data (Prince et al., 2008), the IPAQ short version has been found to be a valid tool for measuring physical activity levels in populations ranging from 18-65 and diverse settings (Craig et al., 2003; Tomioka, Iwamoto, Saeki, & Okamoto, 2011). Specifically, the IPAQ short version was also found to have an acceptable reliability for walking, vigorous and walking activity, all components used in this study (Kurtze, Rangul, & Hustvedt, 2008). Future studies can overcome this issue with the use of multi-sensor device to quantify PA and ultimately energy expenditure. To ensure compliance with the requirement to abstain from eating 3 hours before the experiment, blood glucose could have been measured to help ensure that no consumption of large quantities of food or caloric liquids occurred directly prior to participation (Hendrickson et al., 2015). Finally, convenience sampling was used resulting in the sample population being predominantly white, normal weight, female, college age students, which may limit the generalization of these results to other populations.

Conclusion

This study provides evidence of the differential effects of PA and exercise on food choices. Participants who engaged in higher levels of PA were consistently less likely to choose sweet foods for immediate and delayed consumption. Whereas, individuals who exercised at higher volumes had greater liking, preference and larger ideal portion size for low fat foods. Food liking, preference and ideal portion size were positively interconnected (Bellisle, 1999). High levels of physical activity were associated with lower preference and smaller ideal portion size for non-sweet foods; whereas, high volumes of exercise were associated with greater liking, preference and larger portion size for low fat foods. Further, no statistically significant relationship was found between discounting for money and habitual PA or exercise, suggesting that choices between food options are more sensitive to detect differences in decision making about food related to activity and exercise. Awareness of the effect physical activity and exercise have on food choices may be useful when prescribing exercise interventions.

CHAPTER 6. REFERENCES

Alkahtani, S. A., Dalton, M., Abuzaid, O., Obeid, O., & Finlayson, G. (2016). Validation of the Leeds Food Preference Questionnaire in Arabs. *Asia Pacific Journal of Clinical Nutrition*, *25*(2), 257–264. https://doi.org/10.6133/apjcn.2016.25.2.07

Alonso-Alonso, M., Woods, S. C., Pelchat, M., Grigson, P. S., Stice, E., Farooqi, S., … Beauchamp, G. K. (2015). Food reward system: current perspectives and future research needs. *Nutrition Reviews*, *73*(5), 296–307. https://doi.org/10.1093/nutrit/nuv002

Amlung, M., Petker, T., Jackson, J., Balodis, I., & MacKillop, J. (2016). Steep discounting of delayed monetary and food rewards in obesity: a meta-analysis. *Psychological Medicine*, *46*(11), 2423–2434. https://doi.org/10.1017/S0033291716000866

Apovian, C. M. (2010). The causes, prevalence, and treatment of obesity revisited in 2009: what have we learned so far? *The American Journal of Clinical Nutrition*, *91*(1), 277S-279S. https://doi.org/10.3945/ajcn.2009.28473A

Austin, J., & Marks, D. (2009). Hormonal regulators of appetite. *International Journal of Pediatric Endocrinology*, *2009*. https://doi.org/10.1155/2009/141753

Barlow, P., Reeves, A., McKee, M., Galea, G., & Stuckler, D. (2016). Unhealthy diets, obesity and time discounting: a systematic literature review and network analysis. *Obesity Reviews*, *17*, 810–819. https://doi.org/10.1111/obr.12431

Beaulieu, K., Hopkins, M., Blundell, J., & Finlayson, G. (2016). Does Habitual Physical Activity Increase the Sensitivity of the Appetite Control System? A Systematic Review. *Sports Medicine*, *46*(12), 1897–1919. https://doi.org/10.1007/s40279-016-0518-9

Beaulieu, K., Hopkins, M., Blundell, J., & Finlayson, G. (2017). Impact of physical activity level and dietary fat content on passive overconsumption of energy in non-obese adults. *International Journal of Behavioral Nutrition and Physical Activity*, *14*, 14. https://doi.org/10.1186/s12966-017-0473-3

Beaulieu, K., Hopkins, M., Long, C., Blundell, J., & Finlayson, G. (2017). High habitual physical activity improves acute energy compensation in nonobese adults. *Medicine & Science in Sports & Exercise*, *49*(11), 2268–2275. https://doi.org/10.1249/MSS.0000000000001368

Bellisle, F. (1999). Food choice, appetite and physical activity. *Public Health Nutrition*, *2*(3a). https://doi.org/10.1017/S1368980099000488

Blundell, J. E. (2011). Physical activity and appetite control: can we close the energy gap?: Physical activity and appetite control. *Nutrition Bulletin*, *36*(3), 356–366. https://doi.org/10.1111/j.1467-3010.2011.01911.x

Blundell, J. E., Gibbons, C., Caudwell, P., Finlayson, G., & Hopkins, M. (2015). Appetite control and energy balance: Impact of exercise. *Obesity Reviews*, *16*, 67–76. https://doi.org/10.1111/obr.12257

Blundell, J. E., Stubbs, R. J., Hughes, D. A., Whybrow, S., & King, N. A. (2003). Cross talk between physical activity and appetite control: does physical activity stimulate appetite? *Proceedings of the Nutrition Society*, *62*(03), 651–661. https://doi.org/10.1079/PNS2003286

Bushman, B. A. (2012). How can I use METs to quantify the amount of aerobic exercise? *ACSM's Health & Fitness Journal*, *16*(2), 5–7. https://doi.org/10.1249/01.FIT.0000413045.15742.7b

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Records*, *100*(2), 126–131. https://doi.org/10.2307/20056429

Centers for Disease Control and Prevention. (2017). Adult Obesity Causes & Consequences | Overweight & Obesity | CDC. Retrieved March 9, 2017, from https://www.cdc.gov/obesity/adult/causes.html

Cobb-Clark, D. A., Kassenboehmer, S. C., & Schurer, S. (2014). Healthy habits: The connection between diet, exercise, and locus of control. *Journal of Economic Behavior and Organization*, *98*, 1–28. https://doi.org/10.1016/j.jebo.2013.10.011

Cornier, M.-A., Melanson, E. L., Salzberg, A. K., Bechtell, J. L., & Tregellas, J. R. (2012). The effects of exercise on the neuronal response to food cues. *Physiology & Behavior*, *105*(4), 1028–1034. https://doi.org/10.1016/j.physbeh.2011.11.023

Crabtree, D. R., Chambers, E. S., Hardwick, R. M., & Blannin, A. K. (2014). The effects of high-intensity exercise on neural responses to images of food. *The American Journal of Clinical Nutrition*, *99*(2), 258–267. https://doi.org/10.3945/ajcn.113.071381

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., … Oja, P. (2003). International Physical Activity Questionnaire: 12-Country Reliability and Validity: *Medicine & Science in Sports & Exercise*, *35*(8), 1381–1395. https://doi.org/10.1249/01.MSS.0000078924.61453.FB

DiBonaventura, M. daCosta, & Chapman, G. B. (2008). The effect of barrier underestimation on weight management and exercise change. *Psychology, Health & Medicine*, *13*(1), 111–122. https://doi.org/10.1080/13548500701426711

Donnelly, J. E., Herrmann, S. D., Lambourne, K., Szabo, A. N., Honas, J. J., & Washburn, R. A. (2014). Does increased exercise or physical activity alter ad-libitum daily energy intake or macronutrient composition in healthy adults? A systematic review. *PLoS ONE*, *9*(1). https://doi.org/10.1371/journal.pone.0083498

Donnelly, J. E., Honas, J. J., Smith, B. K., Mayo, M. S., Gibson, C. A., Sullivan, D. K., … Washburn, R. A. (2013). Aerobic exercise alone results in clinically significant weight loss for men and women: Midwest exercise trial 2: Midwest Exercise Trial-2. *Obesity*, *21*(3), E219–E228. https://doi.org/10.1002/oby.20145

Doucerain, M., & Fellows, L. K. (2012). Eating right: Linking food-related decision-making concepts from neuroscience, psychology, and education. *Mind, Brain, and Education*, *6*(4), 206–219. https://doi.org/10.1111/j.1751-228X.2012.01159.x

Douglas, J. A., King, J. A., McFarlane, E., Baker, L., Bradley, C., Crouch, N., … Stensel, D. J. (2015). Appetite, appetite hormone and energy intake responses to two consecutive days of aerobic exercise in healthy young men. *Appetite*, *92*, 57–65. https://doi.org/10.1016/j.appet.2015.05.006

Ely, A. V., Howard, J., & Lowe, M. R. (2015). Delayed discounting and hedonic hunger in the prediction of lab-based eating behavior. *Eating Behaviors*, *19*, 72–75. https://doi.org/10.1016/j.eatbeh.2015.06.015

Emery, R. L., & Levine, M. D. (2017). Questionnaire and behavioral task measures of impulsivity are differentially associated with body mass index: A comprehensive meta-analysis. *Psychological Bulletin*, *143*(8), 868–902. https://doi.org/10.1037/bul0000105

Epstein, L. H., Salvy, S. J., Carr, K. A., Dearing, K. K., & Bickel, W. K. (2010). Food reinforcement, delay discounting and obesity. *Physiology & Behavior*, *100*, 438–445. https://doi.org/10.1016/j.physbeh.2010.04.029

Evero, N., Hackett, L. C., Clark, R. D., Phelan, S., & Hagobian, T. A. (2012). Aerobic exercise reduces neuronal responses in food reward brain regions. *Journal of Applied Physiology*, *112*, 1612–1619. https://doi.org/10.1152/japplphysiol.01365.2011

Farah, N. M. F., Brunstrom, J. M., & Gill, J. M. R. (2012). Using a novel computer-based approach to assess the acute effects of exercise on appetite-related measures. *Appetite*, *58*, 196–204. https://doi.org/10.1016/j.appet.2011.09.008

Fearnbach, S. N., Silvert, L., Keller, K. L., Genin, P. M., Morio, B., Pereira, B., … Thivel, D. (2016). Reduced neural response to food cues following exercise is accompanied by decreased energy intake in obese adolescents. *International Journal of Obesity*, *40*(1), 77–83. https://doi.org/10.1038/ijo.2015.215

Fenzl, N., Bartsch, K., & Koenigstorfer, J. (2014). Labeling exercise fat-burning increases post-exercise food consumption in self-imposed exercisers. *Appetite*, *81*, 1–7. https://doi.org/10.1016/j.appet.2014.05.030

Finlayson, G., Bryant, E., Blundell, J. E., & King, N. A. (2009). Acute compensatory eating following exercise is associated with implicit hedonic wanting for food. *Physiology & Behavior*, *97*, 62–67. https://doi.org/10.1016/j.physbeh.2009.02.002

Finlayson, G., Caudwell, P., Gibbons, C., Hopkins, M., King, N., & Blundell, J. (2011). Low fat loss response after medium-term supervised exercise in obese Is associated with exercise-induced increase in food reward. *Journal of Obesity*, *2011*. https://doi.org/10.1155/2011/615624

Finlayson, G., & Dalton, M. (2012). Hedonics of food consumption: Are food ‘liking’ and ‘wanting’ viable targets for appetite control in the obese? *Current Obesity Reports*, *1*(1), 42–49. https://doi.org/10.1007/s13679-011-0007-2

Finlayson, G., King, N., & Blundell, J. (2008). The role of implicit wanting in relation to explicit liking and wanting for food: Implications for appetite control. *Appetite*, *50*, 120–127. https://doi.org/10.1016/j.appet.2007.06.007

Finlayson, G., King, N., & Blundell, J. E. (2007). Is it possible to dissociate ‘liking’ and ‘wanting’ for foods in humans? A novel experimental procedure. *Physiology & Behavior*, *90*(1), 36–42. https://doi.org/10.1016/j.physbeh.2006.08.020

Griffioen-Roose, S., Finlayson, G., Mars, M., Blundell, J. E., & De Graaf, C. (2010). Measuring food reward and the transfer effect of sensory specific satiety. *Appetite*, *55*, 648–655. https://doi.org/10.1016/j.appet.2010.09.018

Hendrickson, K. L., & Rasmussen, E. B. (2013). Effects of mindful eating training on delay and probability discounting for food and money in obese and healthy-weight individuals. *Behaviour Research and Therapy*, *51*, 399–409. https://doi.org/10.1016/j.brat.2013.04.002

Hendrickson, K. L., Rasmussen, E. B., & Lawyer, S. R. (2015). Measurement and validation of measures for impulsive food choice across obese and healthy-weight individuals. *Appetite*, *90*, 254–263. https://doi.org/10.1016/j.appet.2015.03.015

Horner, K. M., Finlayson, G., Byrne, N. M., & King, N. A. (2016). Food reward in active compared to inactive men: Roles for gastric emptying and body fat. *Physiology & Behavior*, *160*, 43–49. https://doi.org/10.1016/j.physbeh.2016.04.009

Jensen, M. D., Ryan, D. H., Apovian, C. M., Ard, J. D., Comuzzie, A. G., Donato, K. A., … Yanovski, S. Z. (2014). 2013 AHA/ACC/TOS Guideline for the Management of Overweight and Obesity in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. *Circulation*, *129*(25 suppl 2), S102–S138. https://doi.org/10.1161/01.cir.0000437739.71477.ee

King, N. A., Burley, V. J., & Blundell, J. E. (1994). Exercise-induced suppression of appetite: effects on food intake and implications for energy balance. *European Journal of Clinical Nutrition*, *48*(10), 715–724.

Klok, M. D., Jakobsdottir, S., & Drent, M. L. (2007). The role of leptin and ghrelin in the regulation of food intake and body weight in humans: A review. *Obesity Reviews*, *8*(1), 21–34. https://doi.org/10.1111/j.1467-789X.2006.00270.x

Kokkinos, P. (2012). Physical activity, health benefits, and mortality risk. *ISRN Cardiology*, *2012*, 1–14. https://doi.org/10.5402/2012/718789

Kurtze, N., Rangul, V., & Hustvedt, B.-E. (2008). Reliability and validity of the international physical activity questionnaire in the Nord-Trøndelag health study (HUNT) population of men. *BMC Medical Research Methodology*, *8*, 63. https://doi.org/10.1186/1471-2288-8-63

Leng, G., Adan, R. A. H., Belot, M., Brunstrom, J. M., de Graaf, K., Dickson, S. L., … Smeets, P. A. M. (2017). The determinants of food choice. *Proceedings of the Nutrition Society*, *76*(3), 316–327. https://doi.org/10.1017/S002966511600286X

Locey, M. L., Jones, B. A., & Rachlin, H. (2011). Real and hypothetical rewards. *Judgment and Decision Making*, *6*(6), 552–564.

Löckenhoff, C. E., O'Donoghue, T., & Dunning, D. (2011). Age differences in temporal discounting: The role of dispositional affect and anticipated emotions. *Psychology and Aging*, *26*(2), 274–284. https://doi.org/10.1037/a0023280

Marfell-Jones, M., Olds, T., Stew, A., & Carter, L. (2006). *International standards for anthropometric assessment* (2006th ed.). Lower Hutt, New Zealand: International Society for the Advancement of Kinanthropometry.

Martins, C., Morgan, L., & Truby, H. (2008). A review of the effects of exercise on appetite regulation: an obesity perspective. *International Journal of Obesity*, *32*(9), 1337–1347. https://doi.org/10.1038/ijo.2008.98

McNeil, J., Cadieux, S., Finlayson, G., Blundell, J. E., & Doucet, É. (2015). The effects of a single bout of aerobic or resistance exercise on food reward. *Appetite*, *84,* 264–270. https://doi.org/10.1016/j.appet.2014.10.018

Mela, D. J. (2001). Determinants of Food Choice: Relationships with Obesity and Weight Control. *Obesity Research*, *9*(Suppl. 4), 294S-255S.

National Heart Lung and Blood Institute. (2017). Explore Overweight and Obesity: Risk Factors. Retrieved June 20, 2017, from https://www.nhlbi.nih.gov/health-topics/overweight-and-obesity#Risk-Factors

National Institute of Diabetes and Digestive and Kidney Diseases. (2017). Overweight & Obesity Statistics | NIDDK. Retrieved August 27, 2017, from https://www.niddk.nih.gov/health-information/health-statistics/overweight-obesity

Odum, A. L. (2011). Delay discounting: I'm a k, you're a k. *Journal of the Experimental Analysis of Behavior*, *96*(3), 427–439. https://doi.org/10.1901/jeab.2011.96-423

Panek, L. M., Jones, K. R., & Temple, J. L. (2014). Short term aerobic exercise alters the reinforcing value of food in inactive adults. *Appetite*, *81*, 320–329. https://doi.org/10.1016/j.appet.2014.06.102

Perry, B., & Wang, Y. (2012). Appetite regulation and weight control: The role of gut hormones. *Nutrition & Diabetes*, *2*(1), e26. https://doi.org/10.1038/nutd.2011.21

Pomerleau, M., Imbeault, P., Parker, T., & Doucet, E. (2004). Effects of exercise intensity on food intake and appetite in women. *American Journal of Clinical Nutrition*, *80*(5), 1230–1236. https://doi.org/80/5/1230 [pii]

Prescott, J., Young, O., O'Neill, L., Yau, N. J. ., & Stevens, R. (2002). Motives for food choice: a comparison of consumers from Japan, Taiwan, Malaysia and New Zealand. *Food Quality and Preference*, *13*, 489–495. https://doi.org/10.1016/S0950-3293(02)00010-1

Prince, S. A., Adamo, K. B., Hamel, M., Hardt, J., Connor Gorber, S., & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *5*, 56. https://doi.org/10.1186/1479-5868-5-56

Rasmussen, E. B., Lawyer, S. R., & Reilly, W. (2010). Percent body fat is related to delay and probability discounting for food in humans. *Behavioural Processes, 83*, 23–30. https://doi.org/10.1016/j.beproc.2009.09.001

Robertson, S. H., & Rasmussen, E. B. (2018). Comparison of potentially real versus hypothetical food outcomes in delay and probability discounting tasks. *Behavioural Processes*, *149*, 8–15. https://doi.org/10.1016/j.beproc.2018.01.014

Roemmich, J. N., Lambiase, M. J., Lobarinas, C. L., & Balantekin, K. N. (2011). Interactive effects of dietary restraint and adiposity on stress-induced eating and the food choice of children. *Eating Behaviors*, *12*(4), 309–312. https://doi.org/10.1016/j.eatbeh.2011.07.003

Schubert, M. M., Desbrow, B., Sabapathy, S., & Leveritt, M. (2013). Acute exercise and subsequent energy intake. A meta-analysis. *Appetite*, *63*, 92–104. https://doi.org/10.1016/j.appet.2012.12.010

Shepherd, R. (1999). Social determinants of food choice. *Proceedings of the Nutrition Society*, *58*(04), 807–812. https://doi.org/10.1017/S0029665199001093

Singh, M. (2014). Mood, food, and obesity. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00925

Sobal, J., & Bisogni, C. A. (2009). Constructing food choice decisions. *Annals of Behavioral Medicine*, *38*(Suppl. 1), S37–S46. https://doi.org/10.1007/s12160-009-9124-5

Sofis, M. J., Carrillo, A., & Jarmolowicz, D. P. (2017). Maintained physical activity induced changes in delay discounting. *Behavior Modification*, *41*(4), 499–528. https://doi.org/10.1177/0145445516685047

Stuppy-Sullivan, A. M., Tormohlen, K. N., & Yi, R. (2016). Exchanging the liquidity hypothesis: Delay discounting of money and self-relevant non-money rewards. *Behavioural Processes*, *122*, 16–20. https://doi.org/10.1016/j.beproc.2015.11.006

Sze, Y. Y., Slaven, E. M., Bickel, W. K., & Epstein, L. H. (2017). Delay discounting and utility for money or weight loss. *Obesity Science & Practice*, *3*(1), 69–74. https://doi.org/10.1002/osp4.72

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. *Journal of the Academy of Nutrition and Dietetics*, *116*, 501–528. https://doi.org/10.1016/j.jand.2015.12.006

Tomioka, K., Iwamoto, J., Saeki, K., & Okamoto, N. (2011). Reliability and validity of the International Physical Activity Questionnaire (IPAQ) in elderly adults: The Fujiwara-kyo Study. *Journal of Epidemiology*, *21*(6), 459–465. https://doi.org/10.2188/jea.JE20110003

Vabø, M., & Hansen, H. (2014). The relationship between food preferences and food choice: A theoretical discussion. *International Journal of Business and Social Science*, *5*(7), 145–157.

Vatansever-Ozen, S., Tiryaki-Sonmez, G., Bugdayci, G., & Ozen, G. (2011). The effects of exercise on food intake and hunger: Relationship with acylated ghrelin and leptin. *Journal of Sports Science and Medicine*, *10*(2), 283–291.

Verschoor, E., Finlayson, G., Blundell, J., Markus, C. R., & King, N. A. (2010). Effects of an acute α-lactalbumin manipulation on mood and food hedonics in high- and low-trait anxiety individuals. *British Journal of Nutrition*, *104*(04), 595–602. https://doi.org/10.1017/S0007114510000838

Wądołowska, L., Babicz-Zielińska, E., & Czarnocińska, J. (2008). Food choice models and their relation with food preferences and eating frequency in the Polish population: POFPRES study. *Food Policy*, *33*(2), 122–134. https://doi.org/10.1016/j.foodpol.2007.08.001

Weller, R. E., Cook, E. W., Avsar, K. B., & Cox, J. E. (2008). Obese women show greater delay discounting than healthy-weight women. *Appetite*, *51*, 563–569. https://doi.org/10.1016/j.appet.2008.04.010

World Health Organization. (2014). WHO | Facts and figures on childhood obesity. Retrieved June 20, 2017, from http://www.who.int/end-childhood-obesity/facts/en/

World Health Organization. (2016). WHO | Obesity and overweight. Retrieved June 20, 2017, from http://www.who.int/mediacentre/factsheets/fs311/en/