Physical Fitness, Obesity, and Decision Making

Thesis

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By

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Abstract

Obesity is a major public health concern with over a third of Americans considered obese, as defined by a BMI equal to or greater than 30. Obesity is associated with risky decision making which may lead to less engagement in activities that promote weight loss, including diet and physical activity. Engagement in physical activity is associated with less risky decision making and improved executive control. However, the current literature provides limited comparisons of non-obese adults and obese, weight-loss seeking adults on tasks of decision making. The literature also includes limited evaluation of how physical fitness relates to hot decision making, or decision making under ambiguity, and cold decision making, or decision making under risk. The aim of this observational study was to evaluate differences in decision making among non-obese and obese individuals, and to evaluate the relationship of obesity, physical fitness, and decision making. Obese participants (n=50) were recruited and assessed during orientation to a university-based behavioral weight management program, and non-obese participants (n=40) were recruited from the community. All participants completed a demographics questionnaire and four computerized tasks of decision making. Study personnel calculated BMI via height and weight measurements for all participants. Data concerning body fat percentage and meters walked on a 12-minute walk test were collected from obese participants' patient files. The sample was primarily female

(84.4%), and Caucasian (84.4%) with an average age of 42.9 (±11.9) years and an average BMI of 36.3(±13.9). Pearson correlations, analyses of variance, chi-square analyses, and the PROCESS macro in Statistical Analysis Software (SAS) version 9.2 were used to analyze data. Results provide preliminary evidence for physical fitness as a mediator in the relationship between obesity and decision making such that higher BMI is associated with a riskier decision making, as measured by the Iowa Gambling Task, via physical fitness. However, results provide no evidence for physical fitness as a moderator in the relationship between obesity and decision making, nor a difference between obese and non-obese participants in decision making. Results of this study suggest physical fitness may play in important role in the relationship between obesity and risky decision making. Contrary to prior studies, a difference in decision making was not observed between obesity groups. It is notable that the severity of BMI in the obese group (mean 46.8±9.7) is largely unexplored in the decision making literature. Thus, future research is needed to better understand decision making among severely obese individuals, the degree to which obesity may be influenced by interventions targeting decision making, and the influence of physiological factors on decision making processes (e.g., chronic inflammation, vagus nerve activity).

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## Publications

Harris, K. M., Anderson, D. R., Landers, J. D., & Emery, C. F. (in press). Objective and self-report measures of functional status among participants in an outpatient cardiac rehabilitation program. *Journal of Cardiopulmonary Rehabilitation and Prevention*.

## Fields of Study

Major Field: Psychology

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# Chapter 1: Introduction

## *Obesity, Treatment, and Outcomes*

Obesity is a chronic medical condition associated with a number of negative health outcomes (Dixon, 2009), including type II diabetes, heart disease, chronic pain, and sleep apnea. Elevated rates of psychological disorders such as anxiety and depression also are associated with overweight and obesity (Centers for Disease Control and Prevention (CDC), 2015c).

Obesity is often defined using Body Mass Index (BMI). BMI is an approximation of percentage body fat, and is calculated as the ratio of an individual's body weight (in kilograms) to height (in meters squared). Higher BMI indicates greater risk of developing obesity-related health problems. A BMI of 30 and above is classified as obese (U.S. National Library of Medicine, 2015).

Obesity is a growing public health concern in the United States. As of 2012, 34.9% of U.S. adults met criteria for obesity (BMI $\geq$ 30; Ogden, Carroll, Kit, & Flegal, 2014). Obesity is an international problem as well; in 2005 it was estimated that at least 400 million individuals were obese and that the prevalence would continue to increase with time in most countries (Nguyen & El-Serag, 2010). In 2008, medical costs for obese individuals were, on average, more than $1,400 greater than costs for normal weight individuals (Finkelstein, Trogdon, Cohen, & Dietz, 2009).

Obesity is caused by a variety of interacting factors that contribute to and maintain the condition. Some non-modifiable risk factors for obesity include, but are not limited to, genetics, older age, decreased metabolism, and certain medical conditions that prevent engagement in physical activity. However, there also are a number of modifiable risk factors influenced by an individual's lifestyle, including diet and exercise. Obesity is typically characterized by a caloric imbalance in which the amount of calories consumed exceeds the amount used for energy; when there is such an imbalance, typically weight gain occurs (Cooper & Fairburn, 2001). To achieve weight loss, the caloric imbalance must be altered so that the amount of calories consumed is less than the amount used for energy, thus creating an energy deficit. This is typically accomplished through a combination of dietary modification and increased physical activity. However, obese individuals often engage in sedentary lifestyles involving minimal physical activity (Cooper & Fairburn, 2001; Mayo Clinic, 2015).

*Obesity and Cognitive Function*

The inconsistencies observed between the lifestyle changes necessary to lose weight (e.g., dietary modification, increased physical activity) and the lifestyles in which obese individuals often engage (e.g., unhealthy diet, sedentary behavior) has spurred research investigating the role of cognitive function among obese individuals (Wing & Phelan, 2005). Specifically, decision making processes (i.e., response inhibition, willingness to delay reward) have been one focus of studies because impaired decision making may make it more difficult for obese individuals to adopt the lifestyle changes necessary to lose weight (Brogan et al., 2011). Studies often employ one of two different types of decision making tasks. The first type is decision making under ambiguity, or "hot" decision making. Hot decision making tasks, such as the Balloon Analogue Risk Task (BART; Lejuez et al., 2002), typically involve emotion-based, affective reasoning where individuals must rely on immediate feedback within the task, or implicit knowledge, to help guide their decisions (Buelow & Blaine, 2015). Alternatively, there are decision making tasks that measure decision making under risk, or "cold" decision making. Unlike hot decision making tasks, cold decision making tasks involve a rational, cognitive-driven reasoning process in which individuals determine the risks and benefits of available options before making a decision (Buelow & Blaine, 2015). Examples of cold decision making tasks include the Game of Dice Task (GDT, which reflects decisions made under known risk) and the Delay Discounting Task (DDT, which reflects one's ability to delay smaller, immediate rewards in favor of larger rewards in the future; Brand et al., 2002; Kirby & Marakovic, 1996; Weller, Cook, Avsar, & Cox, 2008).

Navas and colleagues (2016) used a cold decision making task which explicitly displayed the probability and magnitude of gains and losses during each trial to assess decision making under risk among obese, overweight, and normal-weight individuals. Results indicated that obese individuals displayed riskier decision making compared to overweight or normal weight individuals. Many studies also have utilized the Iowa Gambling Task (IGT), a measure of response inhibition developed by Bechara and colleagues (1994). The IGT was originally designed as a measure of decision making under risk, or cold decision making; however, recent evidence also suggests that trials at the beginning of the task involve decision making under ambiguity, or hot decision making (Buelow & Suhr, 2009). Thus, the IGT may be utilized as a single task that can provide insight into both hot and cold types of decision making. Studies utilizing the IGT have revealed impaired decision making and poor response inhibition among individuals with gambling addiction and substance dependence (Linnet, Røjskjær, Nygaard, & Maher, 2006; Bechara et al., 2004). Research also has demonstrated that severely obese individuals exhibit poorer response inhibition on the IGT than non-obese (BMI < 30) and normal weight (BMI < 25) individuals (Brogan et al., 2011; Weller, Cook, Avsar, & Cox, 2008). In addition, obese individuals exhibit poorer inhibition than normal weight individuals on cold decision making tasks such as the DDT. Davis, Patte, Curtis, & Reid (2010) studied performance on the IGT and the DDT among three groups of women: obese women with binge eating disorder, obese women without binge eating disorder, and normal weight women. Results indicated that obese women with and without binge eating disorder exhibited greater impulsivity and discounting of future reward than normal weight individuals, but the two groups of obese women did not differ from one another. This pattern of results suggests that poor response inhibition and greater discounting of future reward is associated with obesity. In turn, it is possible that poorer inhibition and delayed discounting may reflect cognitive factors contributing to more immediately rewarding, yet unhealthy behaviors (e.g., sedentary behavior, unhealthy food choices) that maintain obesity.

Decision making also has been evaluated among obese individuals enrolled in diet-focused weight loss interventions. Witbracht and colleagues (2012) administered the IGT to 29 overweight and obese women upon completion of a 12-week, diet-induced weight loss intervention. Weight and fat were significantly reduced by the end of the intervention. Additionally, greater losses of body weight and body fat were associated with better performance on the IGT upon completion of the intervention. These results suggest that less impulsive cognitive response upon completion of a weight loss intervention is associated with greater success during the intervention.

*Aerobic Exercise and Weight Loss*

Regular physical activity is important for achieving and maintaining good health. Frequent exercise is associated with reduced risk for a number of chronic diseases and health conditions including heart disease, type II diabetes, endometrial and lung cancers, and obesity (CDC, 2015b). Physical activity is especially important for individuals attempting to lose weight and/or maintain a healthy weight (CDC, 2015a). Physical activity increases the number of calories used by the body to create energy, thereby contributing to weight loss. The most effective exercise for weight loss is regular aerobic exercise, which has been associated with improved cardiovascular conditioning, lower blood pressure, and reduced body weight in sedentary, non-diabetic, overweight and obese adults (Cleveland Clinic, 2011; Willis et. al., 2012). Examples of aerobic exercise include running, walking, swimming, and cycling. As with dieting, exercise requires an individual to make a conscious decision to engage in a behavior (exercise) that may not be immediately rewarding. Therefore, it is important that obese individuals be able to abstain from impulsive choices that may be highly and immediately rewarding, such as eating high fat foods. Instead, obese individuals must make healthy choices, such as engaging in regular exercise, that may be less immediately rewarding but contribute to achieving the long-term goal of weight loss.

*Physical Activity and Cognitive Function*

The relationship between physical activity and cognitive function has been investigated in numerous studies that have helped elucidate mechanisms by which exercise may affect cognitive function. It has been theorized that acute physical activity may help reallocate cortical function such that activity in motor regions is increased while activity in frontotemporal regions is reduced (Dietrich, 2006; Frith & Dolan, 1996; Kahnemann, 1993; Schneider et al., 2013; Vogt, Schneider, Anneken, & Struder, 2013). In turn, the decrease in prefrontal cortex activity is associated with enhanced executive function capacities during exercise (Schneider et al., 2013). Another potential mechanism by which physical activity may improve executive function includes changes in the anterior cingulate cortex (ACC). Physical activity is associated with increases in top-down, executive control, and this relationship may be mediated by more efficient activation of the ACC (Hillman, Erickson, & Kramer, 2008). Research also has focused on the effect of physical activity on brain-derived neurotrophic factor (BDNF). BDNF is a neurotransmitter necessary for neuron growth and survival, and for long-term potentiation, a process involved in the formation of long-term memory. Acute increases in BDNF secretion have been observed after physical activity (Hillman, Erickson, & Kramer, 2008). Additionally, increased BDNF secretion has been identified as a mechanism by which improved executive function is observed after engagement in long-term physical activity (Leckie et al., 2014). Physical activity may exert change on brain volume as well. Better fitness and fitness improvement is associated with larger volumes of grey matter in the prefrontal and temporal lobes, as well as anterior white matter (Colcombe et al., 2004; Colcombe et al., 2006; Gordon et al., 2008; Marks et al., 2007).

Effects of exercise on cognitive function have been examined in both animal and human studies. In an animal study, Laurence, Labuschagne, Lura, & Hillman (2015) found that exercising rats performed better on tasks involving decision making, problem solving, and persistence than non-exercising rats. In another recent study, Strickland, Feinstein, Lacy, & Smith (2016) found that regular exercise among rats was associated with decreased sensitivity to reward and decreased sensitivity to reinforcement delay.

Physical activity and cognitive function also have been evaluated in human studies. Research suggests that acute exercise in healthy adults is associated with improved cognitive function, including response inhibition, for individuals of all physical fitness levels (Chang et al., 2014; Padilla, Perez, Andres, & Parmentier, 2013). Among older adults (60 years and older), a history of sedentary behavior has been associated with cognitive dysfunction. Conversely, older adults who report past and present engagement in regular physical activity exhibit lower rates of temporal discounting than non-exercising older adults (Tate et al., 2015). This suggests that older adults who have engaged in regular exercise may be better able to forego immediate, smaller rewards when presented with the option of longer-term, future rewards. A meta-analysis of the effects of 18 physical fitness interventions on cognitive functioning in older adults revealed that physical fitness training was associated with improved cognitive functioning. The largest effects of physical activity on cognitive function were observed in executive-control processes, the processes responsible for decision making (Colcombe & Kramer, 2003).

Exercise capacity also has been evaluated as a potential moderator in models of aging and cognitive performance. van Boxtel and colleagues (1997) found that aerobic capacity, specifically peak oxygen uptake ($VO_{2max}$), interacted with age in predicting processing speed. Thus, the association between older age and reduced processing speed may be dependent on aerobic capacity.

*Obesity, Physical Activity, and Cognitive Function*

In order to achieve and sustain weight loss, obese individuals are required to make adaptive decisions to change their diet, exercise habits, and overall lifestyle, and they also often need to forego immediate rewards. For example, when faced with the opportunity to consume a desirable but unhealthy food, obese individuals must forego the immediate reward of consuming the desirable food by abstaining or choosing a healthier food alternative. Obese individuals may face similar choices concerning exercise; when faced with the opportunity to engage in sedentary behavior, obese individuals often must forego the immediate reward of relaxing and instead choose to exercise. Individuals with the inability to make choices that forego immediate reward in order to reach a long-term goal may have greater difficulty achieving weight loss.

Thus, obese individuals engaging in physical activity may not only aid their weight loss efforts, but may also experience the benefit of improved cognitive function and decision making. Due to documented impairments in decision making among obese individuals, physical exercise may be especially important both for physical health and cognitive performance. Among overweight and obese children, Schaeffer and colleagues (2014) found that exercise was associated with increased white matter integrity in the frontotemporal lobe, an area implicated in memory proficiency and decision making (Mabbot et al., 2009). Additionally, long-term exercise has been associated with improved cognitive control among overweight and obese children (Krafft et al., 2014). Thus, among obese children, greater cognitive control, defined as making choices that benefit long-term goals rather than short-term impulsive goals, is associated with greater participation in physical activity.

The relationships among obesity, physical activity, and cognitive function have also been evaluated in obese adults. Langenberg and colleagues (2015) evaluated physical activity and cognitive function (IGT) among 71 severely obese (mean BMI = 46.9), pre-bariatric surgery patients. Most of the sample was either sedentary or engaged in low activity. The study revealed that physical activity level was unrelated to performance on the IGT. However, in a study of 29 obese individuals (mean BMI = 38.5), Monleón and colleagues (2015) found that participation in physical activity was associated with increased cardiorespiratory fitness, reduced BMI, and improved performance on a vigilance task requiring cognitive control. Thus, as in obese children, cognitive function among obese adults may improve following a multi-week intervention designed to increase physical activity engagement.

Although Langenberg and colleagues (2015) evaluated the relationship of physical activity and decision making among obese individuals, their study did not include a non-obese comparison group, and had limited assessment of decision making. This study improved upon the study by Langenberg and colleagues (2015) by assessing decision making performance using four different computerized tasks of hot and cold decision making, which allowed for the comparison of performance among tasks evaluating different decision making processes, and this study compared decision making performance between obese and non-obese individuals. The study by Davis and colleagues (2010) allowed for the comparison of hot and cold decision making among obese and normal weight individuals, but one-third of the sample had been diagnosed with binge eating disorder and the study included only women. This study included both men and women, and included participants regardless of binge eating status, thereby increasing generalizability of results documented in prior research (e.g., Witbracht et al., 2012; Davis et al., 2010). In addition, differences in decision making performance were evaluated among obese weight management patients and non-obese individuals, as well as the degree to which differences are greater in hot or cold decision making processes. This study improved upon the study by Monleón and colleagues (2015) by evaluating physical fitness as a predictor of both hot and cold decision making, and as a mediator and moderator in the relationship between obesity and decision making. The degree to which individual differences in physical fitness may be associated with different kinds of decision making processes was explored, in addition to evaluating the degree to which physical fitness may exacerbate decision making impairment among obese individuals.

There were three primary aims of the study. First, differences in decision making performance were evaluated among obese weight management patients and non-obese individuals from the community. Second, the degree to which physical fitness mediates the relationship between obesity and decision making in obese weight management patients was evaluated. Third, the degree to which physical fitness moderates the relationship between obesity and decision making in obese weight management patients was evaluated.

There were three study hypotheses:

*Hypothesis #1*

*Non-obese participants would exhibit less risky decision making than obese participants.*

- *Although no prior study has directly compared the performance of obese and non-obese individuals on measures of both hot and cold decision making, it was expected that the effect size for obesity group differences would be greater for tasks involving hot decision making.*

*Hypothesis #2*

*The relationship between obesity (i.e., BMI, percentage body fat) and decision making performance among obese participants would be mediated by physical fitness (i.e., distance walked during a standardized walk test).*

- *Although no prior study has evaluated physical fitness as it relates to both hot and cold decision making, it was expected that the effect size for physical fitness as a mediator would be greater on tasks involving hot decision making.*

*Hypothesis #3*

*The relationship between obesity (i.e., BMI, percentage body fat) and decision making performance among obese participants would be moderated by physical fitness (i.e., distance walked).*

- *While this relationship has not been previously evaluated, it was expected that the effect size for physical fitness as a moderator would be greater on tasks involving hot decision making.*

## Chapter 2: Methods

*Participants*

This is an archival study utilizing data from the Decision Making and Health study. Participants were 50 obese (BMI $\geq$ 30) patients enrolled in the Ohio State University Living Well program and 40 non-obese (BMI < 30) individuals from the community. The Living Well program is an empirically supported weight management program offered at The Ohio State University Center for Wellness and Prevention in which patients attend individual appointments and group educational classes pertaining to nutrition, behavior change, and exercise (Wexner Medical Center, 2015). All participants were at least 18 years of age and endorsed no history of depression, eating pathology, or significant head trauma (i.e., leading to the individual being unconscious for greater than ten minutes). As shown in Table 1, the full sample was mostly female, white, and employed either part-time or full-time.

*Procedures*

Potential obese participants were recruited during the first of two orientation sessions to the Living Well program at the Ohio State University Center for Wellness and Prevention. At the time of recruitment, study personnel screened potential participants for history of depression, eating pathology, and significant head trauma. Patients who met study criteria and were willing to participate in the study provided written consent for the study and for access to their medical records. Study personnel then scheduled a one-hour assessment to take place the following week at the Center for Wellness and Prevention.

Potential non-obese participants were recruited using community flyers and the ResearchMatch database, an online registry of individuals from the community willing to participate in research studies. Potential participants were contacted by study personnel via telephone and screened for history of depression, eating pathology, and significant head trauma. Study personnel then scheduled a one-hour assessment to take place the following week at the Center for Wellness and Prevention.

Obese participants began the one-hour assessment by completing a packet of self-report questionnaires. Non-obese participants began the assessment by providing written consent for the study in addition to having their height and weight measured and recorded. Non-obese participants then completed a packet of self-report questionnaires. Following the questionnaires, all participants were instructed in completing four computerized decision making tasks administered in random order. All participants were paid with a $10 Target gift card at the end of the assessment as reimbursement for their participation. After the assessment was complete, study personnel accessed obese participants' medical records to obtain data pertaining to BMI, percentage body fat, and distance walked during exercise testing.

*Measures*

The following study outcome measures were collected from various sources, as noted below:

**Demographics –** Participants completed a demographic and medical history questionnaire including information regarding age, sex, marital status, race, level of education, current employment, health history, and weight history.

**Body Mass Index (BMI) –** Height and weight of each obese and non-obese participant were measured using a portable stadiometer and digital high-capacity scale. The data were then utilized by study personnel to calculate BMI.

Measures of body fat and physical fitness: The following data were collected from each obese patient's medical record.

**Percentage Body Fat** – The percentage of each obese participant's total body mass that is attributable to fat was measured and recorded by Living Well staff. Circumference measurements were recorded for each participant's upper arm, forearm, abdomen, hips, thigh, and calf. Consistent with the American College of Sports Medicine (2013) guidelines, the measurements were then transformed and entered into age- and gender-specific equations to calculate percentage body fat.

**12-Minute Walk Test –** During this test, obese participants were instructed to walk continuously for 12 minutes on a level indoor track located in the Ohio State University Martha Morehouse Medical Pavilion. Participants were encouraged to walk as far as possible during the allotted time while maintaining a comfortable pace. Data collected by study personnel included total distance walked in meters, which was measured at the completion of the walk test. Total distance walked during the 12-minute walk test is positively associated with maximal oxygen uptake (peak $VO_2$) among obese children and adolescents, as well as among individuals with chronic obstructive pulmonary disease and children with persistent asthma (Calders et al., 2008; Bernstein et al., 1994; Weisberger et al., 2009). The 12-minute walk test and 6-minute walk test have demonstrated acceptable inter-rater and intra-rater reliability in the fitness evaluation of stroke patients (Kosak & Smith, 2005). Performance on the 6-minute walk test (meters walked) is associated with measures of fitness in a variety of populations, including obese and morbidly obese individuals, and patients with congenital heart disease, chronic obstructive pulmonary disease, and lung cancer (Hulens et al., 2003; Beriault et al, 2009; Moalla, Gauthier, Maingourd, & Ahmaidi, 2005; Marek et al., 2011; Ha et al., 2016).

<u>Measures of decision making</u>: The following computerized measures were administered to all participants to evaluate decision making capacity.

**Iowa Gambling Task (IGT):** For this task, participants are instructed to select a series of cards from one of four decks displayed on the computer screen. Each card selection will result in either a monetary profit or loss. Participants are instructed to make 100 total card selections with the goal of maximizing their profit. Unknown to participants, decks A and B are "disadvantageous", yielding greater loss in the long-term, while decks C and D are "advantageous", and will yield greater long-term profit. The IGT has demonstrated validity in a variety of populations, such as pathological gamblers, individuals with chronic substance abuse, and individuals with frontal lobe damage (Buelow & Suhr, 2009). The first 40 selections in the IGT are considered to be the learning phase because participants are learning the outcomes they can expect from their selections. The final 60 selections are considered decision making under risk as participants have had time to learn deck patterns. For the current study, the percentage of advantageous selections made in the first 40 selections will be used to measure hot decision making performance, and the percentage of advantageous selections made in the last 60 selections will be used to measure cold decision making performance. Higher percentages will indicate greater tendency to make advantageous choices under ambiguity and under risk, respectively.

**Balloon Analogue Risk Task (BART):** The BART is a computerized task that was designed by Lejuez and colleagues (2002) to measure decision making under ambiguity by replicating situations in which risk-taking is rewarded initially, but eventually is punished. In this task, participants are presented with a tiny balloon on the computer screen, a button stating "Press this button to pump up the balloon," a button stating "Press to collect $$$," a numerical figure displaying total money earned, and another numerical figure displaying money earned on the trial. In each trial, participants click the computer mouse to pump the balloon as much as they desire. Each pump earns the participant five cents. Participants are instructed that they should press “Collect $$$” when they have pumped as much as they want to during the trial which transfers the money earned during that trial to their total earned figure, thus ending that trial. Participants complete this process 30 times, either collecting money or popping the balloon each time. The number of pumps prior to popping varies with each balloon. If the participant causes the balloon to pop by inflating it too many times then he/she loses all money earned during that trial. Research by Lejuez and colleagues (2003) has shown impulsivity to correlate with BART performance. In-session correlations across blocks of trials is high ($r = .82$). Additionally, the BART has been shown to demonstrate strong test-retest reliability (Buelow, under review). For the current study, the average adjusted number of pumps made across the 30 trials was used to assess decision making performance, with a greater average number of pumps indicating more impulsive behavior.

**Game of Dice Task (GDT):** The GDT is a computerized task designed by Brand and colleagues (2002) to measure decision making under risk. Participants are presented with a die and are asked to predict the number generated by “rolling” the die. Participants are presented with different options for their “bet”: picking a single number, a set of two numbers, or a set of three numbers that the die will land on. If the die lands on a predicted side then the participant wins the amount of money corresponding to the selection. Conversely, if the die lands on a side different than predicted, then the participant loses the amount of money corresponding to the selection. Single number predictions yield the greatest profit if the die lands on the predicted number, but also yield the greatest loss if the die lands on any number other than the predicted number. Profits and losses become smaller as the set of numbers selected becomes larger. Participants repeat this process 18 times with the goal being to maximize profit by the end of the trials. For the current study, the percentage of advantageous die throws made in the 18 trials was used in analyses.

**Delay Discounting Task (DDT):** The DDT developed by Kirby and Marakovic (1996) measures one's preferences for smaller, more immediate rewards compared to larger, delayed rewards. Participants are presented with 27 hypothetical scenarios in which they are asked to choose whether they prefer to receive a smaller, immediate reward or a larger, delayed reward. The monetary difference between the immediate and delayed reward, as well as the length of the delay, varies throughout the assessment. Research in substance-dependent samples has demonstrated the validity of the DDT, with individuals reporting greater substance dependence engaging in greater delay discounting (preference for immediate reward) (Kirby & Petry, 2003; Kirby, Petry, & Bickel, 1999). K-values are calculated for participant response towards small, medium, and large delayed reward sizes. High k-values indicate that the delayed rewards are being discounted more steeply and that the participant is more impulsive. For the current study, the average k-value for all reward sizes combined (all 27 trials) was used in analyses.

*Statistical Analyses*

Statistical Analysis Software (SAS) version 9.2 was used to complete all analyses for this study. A one-way ANOVA was used to confirm a difference in BMI between obese weight management participants and non-obese participants from the community. Next, one-way analyses of variance (ANOVA) and chi-square analyses were used to evaluate differences between obese and non-obese participants on all demographic variables (age, sex, race, education, profession, work status, and marital status). Demographic variables that differed between obesity groups were used as covariates in analyses evaluating differences in decision making performance between obesity groups (hypothesis #1). Additionally, one-way ANOVAs and Pearson correlations were used to evaluate the relationships of demographic variables to decision making outcome variables. Demographic variables significantly associated with an outcome were used as covariates in PROCESS analyses evaluating that particular outcome (hypotheses #2 and #3).

One-way ANOVAs were used to evaluate differences in decision making performance among obese and non-obese participants (hypothesis #1). Specifically, one-way ANOVAs were conducted to evaluate obesity group differences on the BART, GDT, DDT, percentage of selections from each of the four decks of the IGT, and the average hot and cold trials of the IGT. Any demographic variable associated with each decision making performance variable was statistically controlled in the ANOVA evaluating group differences on the relevant decision making variable. Thus, for hypothesis #1, a total of nine ANOVAs were conducted.

The PROCESS (Hayes, 2013) Macro in SAS, which included 10,000 bootstrap samples with 95% confidence intervals, was used to evaluate physical fitness as a mediator in the relationship between obesity and decision making performance among obese weight management patients (hypothesis #2). Specifically, distance walked was tested as a mediator and BMI was tested as a primary predictor of nine decision making outcome variables for a total of nine mediation analyses. In addition, distance walked was tested as a mediator and body fat percentage was tested as a secondary predictor of the nine decision making variables for an additional nine mediation analyses to test hypothesis two. Any demographic variable significantly associated with each decision making performance variable was statistically controlled in the model predicting the relevant decision making variable.

The PROCESS (Hayes, 2013) Macro in SAS was also used to evaluate physical fitness as a moderator in the relationship between obesity and decision making performance among obese weight management patients (hypothesis #3). Specifically, distance walked was tested as a moderator and BMI was tested as a primary predictor of nine decision making outcome variables for a total of nine moderation analyses. In addition, distance walked was tested as a moderator and body fat percentage was tested as a secondary predictor of the nine decision making variables for an additional nine moderation analyses to test hypothesis three. Any demographic variable significantly associated with each decision making performance variable was statistically controlled in the model predicting the relevant decision making variable.

All data analyses were conducted a second time without the 14 male participants to evaluate the degree to which the relatively small number of male participants might introduce unwanted heterogeneity in the decision making outcomes.

## Chapter 3: Results

One-way ANOVAs and Chi-square analyses were used to evaluate differences between obese and non-obese participants in potential covariates (i.e., age, sex, race, education, profession, work status, and marital status), and to confirm BMI differences between the two groups. As shown in Table 2 and Table 3, obese and non-obese participants differed in BMI as expected, but also differed in profession. Participants from the two groups also differed in years of education, despite efforts to match on this variable. Therefore, in analyses of obesity group differences on decision making outcomes (hypothesis #1), education and profession were included as covariates.

*Hypothesis #1*

One-way ANOVA was used to evaluate differences among obese and non-obese participants on decision making outcomes, with years of education and profession included as covariates. As shown in Tables 4 and 5, no differences were found between obesity groups on any decision making study outcome. Among obese participants (n=50), Pearson correlations and ANOVAs were used to evaluate the relationship of demographic variables to decision making outcomes. As shown in Table 6, years of education was positively associated with number of advantageous dice throws on the GDT. As shown in Table 7, a sex difference was observed in the percentage of choices made from deck D, an advantageous deck, on the IGT, and a marital status difference was observed in DDT performance. Therefore, years of education was included as a covariate in mediation and moderation analyses when GDT was the study outcome, sex was included as a covariate when deck D of the IGT was the study outcome, and marital status was included as a covariate when DDT was the study outcome (hypotheses #2 and #3).

*Hypothesis #2*

The PROCESS (Hayes, 2013) macro in SAS was used to evaluate physical fitness (i.e., distance walked) as a mediator in the relationship between obesity and decision making outcomes. Analyses indicated that physical fitness mediated the relationship between BMI and percentage of selections from decks A (*ab* = 0.17; 95% CI = 0.0049 to 0.4265) and C (*ab* = -0.30; 95% CI = -0.6809 to -0.0173) on the IGT, but there was not a mediation effect for other IGT outcomes or for any other decision making outcome (BART, GDT, DDT). Results of the significant mediation effects are noted in Table 9, and shown in Figures 1 and 2. Physical fitness also mediated the relationship between body fat percentage and percentage of selections from deck C on the IGT (*ab* = -0.19; 95% CI = -0.4769 to -0.0230), as noted in Table 10 and shown in Figure 3. However, no other relationships between body fat and decision making outcomes were mediated by physical fitness.

Results from the mediation analyses suggest that obese participants one unit greater in BMI are estimated to be 0.17 units higher in percentage of choices made from deck A on the IGT as a result of physical fitness. Additionally, the analyses suggest that obese participants one unit greater in BMI are estimated to be 0.30 units lower in percentage of choices made from deck C on the IGT as a result of physical fitness. Furthermore, obese participants one unit greater in body fat percentage are estimated to be 0.19 units lower in percentage of choices made from deck C on the IGT as a result of physical fitness.

*Hypothesis #3*

PROCESS (Hayes, 2013) was also used to evaluate physical fitness as a moderator in the relationship between obesity and decision making outcomes (i.e., BART, GDT, DDT, individual decks on the IGT, hot decision making, cold decision making). As shown in Tables 11-28, no relationships between BMI and decision making outcomes or body fat and decision making outcomes were moderated by physical fitness. However, the model evaluating physical fitness as a moderator in the relationship between BMI and GDT was noteworthy ($R^2$ increase due to interaction = .056, $p$ = .075).

*Female-Only Analyses*

Because sex differences have been observed on tasks of decision making in previous research (Evans & Hampson, 2015; van den Bos, Homberg, & de Visser, 2013), and because most participants in this study were women, all analyses were repeated without the 14 men in the sample to reduce heterogeneity and to account for any “noise” that might be introduced by the relatively small subsample of men. As in the full sample, no differences were observed between obese and non-obese participants on decision making tasks (hypothesis #1). However, unlike the full sample, physical fitness did not mediate any relationships between obesity and decision making (hypothesis #2), possibly due to reduced statistical power; and no moderation effects were observed (hypothesis #3).

*Post-hoc Analyses*

In accordance with statistical methods used in prior studies, post-hoc analyses were conducted to evaluate combined advantageous deck choices (decks C+D), combined disadvantageous deck choices (A+B), and net score (decks C+D minus decks A+B) across all trials of the IGT as decision making outcomes (Bechara et al., 1994; Brogan et al., 2011; Langenberg et al., 2015). Results indicated no difference in these decision making outcomes between obesity groups (hypothesis #1), nor a role of physical fitness as a mediator or moderator between obesity and these decision making outcomes.

Post-hoc analyses also were conducted using the full sample to evaluate the relationship of BMI to decision making outcomes. Results, shown in Table 8, indicate that BMI was positively associated with percentage of selections from deck B of the IGT ($r = 0.21$, $p = 0.045$), and negatively associated with percentage of advantageous selections made in the last 60 trials of the IGT (i.e., cold decision making; $r = -0.24$, $p = 0.025$). Additionally, the relationship between BMI and discounting of future reward on the DDT was noteworthy ($r = 0.19$, $p = 0.071$).

# Chapter 4: Discussion

No prior research has investigated physical fitness as a mediator or moderator in the relationship between obesity and decision making, but results of the current study suggest that physical fitness may play a mediating role in the relationship. Specifically, higher BMI and body fat percentage were related to lower exercise capacity which, in turn, was associated with riskier decision making. However, physical fitness was a mediator for only two of the nine decision making outcomes in this study: deck A (disadvantageous deck) and deck C (advantageous deck) on the IGT. No significant mediation or moderation models were found for the remaining seven decision making outcomes. Thus, the current study provides preliminary evidence that obesity is related to aspects of decision making through physical fitness.

These results can be further evaluated by examining the unique characteristics of the four IGT card decks. Decks A and B result in equal net loss over 100 trials, as do decks C and D. However, choosing decks A or C results in more frequent (50% of trials), but smaller magnitude punishments than decks B or D, which result in less frequent (10% of trials), but larger magnitude punishments (Okdie, Buelow, & Bevelhymer-Rangel, 2016). The data from this study suggest that obesity is related to decision making through physical fitness when punishments are more frequent (i.e., easier to predict their occurrence) but relatively small. This punishment schedule may be perceived as less risky than one characterized by less frequent (i.e., more difficult to predict their occurrence) but relatively large punishments.

Due to the novelty of the relationships being evaluated, there are no prior studies for comparison. It is unclear if the negative results are a function of low power. Significant effects were found only for the IGT, which is unique in measuring both hot and cold decision making. Other measures focus on hot decision making only (BART), cold decision making only (GDT), or discounting of future reward (DDT). In comparison to the IGT, the BART and GDT are limited in the type of decision making they assess. Therefore, it is possible that the positive results observed exclusively on IGT outcomes in the current study could be attributed to the unique ability of the IGT to measure both hot and cold decision making in a single task.

Prior studies suggest that performance on decision making tasks such as the IGT is positively associated with education (Davis et al., 2008). Therefore, any differences observed between obese and non-obese individuals on decision making tasks should be exacerbated by differences in education. However, this was not the case in the current study, despite non-obese participants having more years of education on average.

Although prior studies found differences between obese and non-obese individuals on measure of decision making, the current study did not find differences, possibly because the sample for this study may differ in important ways from prior samples. Prior studies in this area have recruited obese individuals with average

BMI’s ranging from to 33.50 to 41.45, but the average BMI in the current study was 46.77. The sample recruited by Langenberg and colleagues (2015) had an average BMI of 46.9, but did not recruit a comparison group. Aside from the study by Langenberg and colleagues, participants with severe obesity have been largely unexplored in the obesity literature, especially in the decision making literature. Post hoc analyses were conducted excluding the 36 severely obese (BMI $\geq$ 40) participants while including the 14 non-severely obese (BMI 30-39.9) participants to determine if the unusually high BMI in this sample had an influence on the results observed, but the results concerning obesity group differences remained unchanged. However, the number of non-severely obese participants included in post hoc analyses may have been too small to detect differences between obesity groups.

Unlike obese individuals in several other studies, participants in this study already demonstrated adaptive decision making by enrolling in a weight management program. To determine if this may have contributed to the lack of differences observed between obesity groups, mean net scores on the IGT calculated in post-hoc analyses were used to compare decision making performance in the current study to prior studies. The mean net score for obese participants in the current study (-3.87) suggests a greater tendency to choose disadvantageously than obese participants in studies by Brogan and colleagues (0.48) and Langenberg and colleagues (17.1). The mean net score for non-obese participants in this study was 4.64, which is lower than the mean for the non-obese group in the study by Brogan and colleagues (16.36).

Therefore, the lack of differences observed between the two groups may be due to riskier than expected decision making by non-obese participants in the study.

Interestingly, when obese and non-obese participants were grouped together in post-hoc analyses, higher BMI was related to greater percentage of selections from disadvantageous deck B on the IGT, reflecting riskier decision making, and a trend toward a greater discounting of future reward. These direct relationships were not observed in analyses of obese participants only. Thus, evaluating body fat on a continuum rather than dividing the sample into obese and non-obese groups facilitated evaluation of the relationship of body weight to decision making.

Previous research has found sex differences on decision making tasks. These data indicated that women made advantageous choices (Deck D) more often than men. but no other sex differences were observed, possibly due to the small number of men in the sample.

*Limitations*

There are several limitations of this study. First, archival data were used, resulting in limited control over study design (e.g., education level of the sample, sample size). The sample was primarily female and Caucasian, limiting the degree to which these findings may apply to less homogeneous groups. Additionally, the findings may not generalize widely to obese or non-treatment seeking individuals because participants were recruited from a university-based behavioral weight management program, and participants on average were severely obese. Also, the cross-sectional study design limits the ability to identify causation among variables included in the current study.

Maximal oxygen uptake is considered the gold standard measure of cardiorespiratory fitness (Di Thommazo-Luporini et al., 2016; Pate, Oria, & Pillsbury, 2012). Several studies have evaluated the relationship of maximal oxygen uptake to obesity and psychosocial variables (van Boxtel et al., 1997; García-Hermoso, 2016; Maddison et al., 2012). Because it is the gold standard measure of cardiorespiratory fitness, maximal oxygen uptake would have been an ideal measure of physical fitness in the current study. However, sedentary, severely obese individuals in the current sample may have found the exercise required to measure maximal oxygen uptake to be too intense to perform. Also, performance on the 12-minute walk test has been associated with maximal oxygen uptake in previous studies (Calders et al., 2008; Bernstein et al., 1994; Weisberger et al., 2009). Therefore, it appeared that the submaximal 12-minute walk test utilized in the current study was appropriate for the current sample of obese individuals. However, it is possible that some participants experienced physical symptoms that may have compromised their walk test performance (e.g., knee pain).

The non-obese group included 10 participants with an overweight BMI (25-29.9). Additionally, BMI for 36 of the 50 obese participants was in the scarcely researched severe obesity range (BMI ≥ 40). It is possible that inclusion of overweight individuals in the non-obese group and severely obese individuals in the obese group may have contributed to results inconsistent with prior research. When analyses were conducted excluding overweight and severely obese participants, differences in cold decision making were found on the IGT, with healthy weight (BMI < 25) participants (n = 30) demonstrating less risky decision making in the last 60 trials than obese (BMI 30-39.9) participants (n = 14). It is possible that a larger sample of healthy and obese participants defined in this manner would have produced results more consistent with prior research.

Decision making among obese participants in the current study was more risky than decision making of obese participants seeking weight loss in previous studies. Therefore, one may have expected an even larger difference in risky decision making between obesity groups in this study. However, the non-obese group in the current study also demonstrated riskier decision making than comparison groups in prior research. Additionally, when overweight participants were removed from the non-obese group, no differences between obesity groups were observed. Hypothesis #1 was generated assuming that non-obese participants would demonstrate the same level of risky decision making as found in prior studies. Therefore, the relatively risky decision making by non-obese participants in the current study may have contributed to the null results.

*Implications*

This study contributes to the literature on obesity, decision making, and physical fitness in a number of ways. This is the first known study to assess the role of physical fitness in the relationship between obesity and decision making. Results provide mixed support for the role of physical fitness as a mechanism by which obesity and cognitive function (i.e., decision making) are related. However, data for the most widely used measure of decision making (IGT) was suggestive of a mediating relationship. With higher levels of BMI, fitness level was diminished, and risky decision making increased. This model fits with the hypotheses based on previous studies. Chronic inflammation and disruption of vagal afferent signaling are evident in obesity and are associated with impaired cognitive function among obese adults (Spyridaki et al., 2014). Exercise and higher levels of physical fitness are associated with reduced chronic inflammation among obese adults (Beavers, Brinkley, & Nicklas, 2010; You, Arsenis, Disanzo, & LaMonte, 2013).

Obese participants in the current study were predominantly severely obese, a segment of the obese population that has received relatively little attention in the research literature. Because many individuals seeking weight loss are severely obese, it is important to understand decision making in this population, and how it may differ from non-severely obese and non-obese individuals. The unexpected results from the current study suggest that more investigation is needed to better understand decision making among severely obese individuals seeking weight loss.

*Future Directions*

Results of the current study provide additional directions for future research. This study found evidence for the role of physical fitness in the relationship between obesity and decision making. The current study operationalized physical fitness with distance walked on the 12-minute walk test. Future studies evaluating these relationships should consider alternate measures of physical fitness (e.g., graded exercise test) in addition to the 12-minute walk test to assess the reliability of results, and to confirm the relevance of cardiorespiratory fitness for decision making in severely obese adults. Future studies also should explore changes in physical fitness over the course of participation in a behavioral weight management program, and the relationship of those changes to decision making to evaluate the relevance of physical fitness changes on decision making among obese individuals.

Because higher BMI was associated with less adaptive decision making tendencies in the overall sample, this may be important to address in future weight loss intervention research with severely obese individuals. Specifically, the degree to which severe obesity may be reduced with interventions designed to improve decision making will be interesting to evaluate in future research.

In addition, future research should include measures of physiological factors associated with decision making and obesity (e.g., chronic inflammation, vagus nerve activity) that may differ between obese individuals seeking weight loss and non-obese individuals.

Other factors that should be evaluated in future studies include behavioral inhibition and approach systems (BIS/BAS), which are theorized to be two motivational systems that influence behavior. Specifically, the BIS system regulates avoidance (i.e., inhibition) motives in scenarios where the goal is to avoid something unpleasant. The BAS system regulates appetitive (i.e., approach) motives in scenarios where the goal is to move toward something desired (Carver & White, 1994).

Although studies of obese individuals have revealed that high sensitivity to reward (BAS) is associated with stronger food cravings, higher BMI, overeating, and preference for foods high in fat and sugar (Davis et al., 2005; Davis et al., 2004; Franken & Muris, 2005), little research has assessed the influence of BIS/BAS in obese individuals attempting to lose weight. BIS/BAS may be useful constructs to evaluate in future research on obesity and decision making, specifically as they relate to engagement in adaptive and maladaptive health behaviors affecting weight loss.

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Appendix A: Tables

*Table 1.* Demographic measures for the full sample (n=90)

| | M | SD |
|---|---|---|
| **Age** | 42.89 | 11.94 |
| **BMI** | 36.31 | 13.92 |
| **Education (Years)** | 15.89 | 2.23 |

| | N | % |
|---|---|---|
| **Sex** | | |
| Female | 76 | 84.44 |
| Male | 14 | 15.56 |
| **Ethnicity** | | |
| White | 76 | 84.44 |
| Non-white | 14 | 15.56 |
| **Marital Status** | | |
| Married | 56 | 62.22 |
| Single, Never Married | 26 | 28.89 |
| Divorced/Separated | 8 | 8.89 |
| **Profession** | | |
| White-collar (e.g. Higher Executive, Manager, Sales) | 71 | 78.89 |
| Blue-collar (e.g., Skilled/Semi-Skilled/Unskilled Manual Labor) | 12 | 13.33 |
| Student | 6 | 6.67 |
| Disabled/No Occupation | 1 | 1.11 |
| **Work Status** | | |
| Employed Full-Time/Employed Part-Time | 77 | 85.56 |
| Unemployed/Retired | 9 | 10.00 |
| Homemaker | 4 | 4.44 |

*Table 2.* Mean scores and standard deviations for BMI and demographic variables by obesity group.

| | Obese (n=50) | Non-Obese (n=40) |
|---|---|---|
| **BMI** | 46.77 (9.7) | 23.25 (3.1)* |
| **Age** | 44.00 (11.8) | 41.50 (12.1) |
| **Education (Years)** | 15.15 (2.2) | 16.81 (1.9)* |

Note: * $p<0.05$, obesity group effect

*Table 3.* Chi-square results for demographic variables by obesity group.

| | Obese | Non-Obese |
|---|---|---|
| | Frequency (Percentage) | |
| **Sex** | | |
| Female | 43 (86%) | 33 (82.5%) |
| Male | 7 (14%) | 7 (17.5%) |
| **Ethnicity** | | |
| White | 39 (78%) | 37 (92.5%) |
| Non-White | 11 (22%) | 3 (7.5%) |
| **Marital Status** | | |
| Married | 29 (58%) | 27 (67.5%) |
| Single, Never Married | 15 (30%) | 11 (27.5%) |
| Divorced/Separated | 6 (12%) | 2 (5%) |
| **Profession** | | |
| White Collar | 41 (82%) | 30 (75%)* |
| Blue Collar | 9 (18%) | 3 (7.5%) |
| Student | 0 (0%) | 6 (15%) |
| Disabled/No Occupation | 0 (0%) | 1 (2.5%) |
| **Work Status** | | |
| Employed Full-Time/Part-Time | 40 (80%) | 37 (92.5%) |
| Unemployed/Retired | 8 (16%) | 1 (2.5%) |
| Homemaker | 2 (4%) | 2 (5%) |

Note: * $p<0.05$, obesity group effect

*Table 4.* Mean scores and standard deviations for decision making outcomes by obesity group (controlling for education and profession).

| | Obese (n=50) | Non-Obese (n=40) |
|---|---|---|
| BART | 26.30 (2.2) | 26.52 (2.5) |
| GDT | 12.43 (0.7) | 11.48 (0.8) |
| DDT | 0.03 (0.0) | 0.02 (0.0) |
| Total A | 15.56 (1.3) | 16.33 (1.4) |
| Total B | 36.38 (2.0) | 31.35 (2.3) |
| Total C | 20.29 (2.0) | 21.79 (2.2) |
| Total D | 27.77 (2.1) | 30.53 (2.4) |
| Hot DM | 42.06 (2.7) | 42.36 (3.0) |
| Cold DM | 52.06 (3.0) | 58.96 (3.4) |

Note: BART=Average number of pumps adjusted for only non-exploded balloons on Balloon Analogue Risk Task, GDT=Advantageous dice throws on Game of Dice Task, DDT=Discounting of future reward on Delay Discounting Task, Total A=Percent of choices made from deck A on IGT, Total B=Percent of choices made from deck B on IGT, Total C=Percent of choices made from deck C on IGT, Total D=Percent of choices made from deck D on IGT, Hot DM=Percent of first 40 choices made from advantageous decks on IGT, Cold DM=Percent of last 60 choices made from advantageous decks on IGT

*Table 5.* Analysis of variance comparing non-obese and obese participants on decision making task performance, controlling for education and profession (n=90).

| | df | Type III Sum of Squares | F | $\eta^2$ | *p* |
|---|---|---|---|---|---|
| **Outcome: BART** | | | | | |
| Obesity Group | 1 | .90 | .00 | .000 | .950 |
| Education Years | 1 | 15.77 | .07 | | .792 |
| Profession | 1 | 11.69 | .05 | | .820 |
| **Outcome: GDT** | | | | | |
| Obesity Group | 1 | 16.44 | .66 | .008 | .417 |
| Education Years | 1 | 264.88 | 10.70 | | .002 |
| Profession | 1 | 40.98 | 1.66 | | .202 |
| **Outcome: DDT** | | | | | |
| Obesity Group | 1 | .00 | 1.89 | .022 | .173 |
| Education Years | 1 | .00 | .33 | | .569 |
| Profession | 1 | .00 | .07 | | .797 |
| **Outcome: Total A** | | | | | |
| Obesity Group | 1 | 10.79 | .15 | .002 | .698 |
| Education Years | 1 | 2.65 | .04 | | .847 |
| Profession | 1 | 10.90 | .15 | | .697 |
| **Outcome: Total B** | | | | | |
| Obesity Group | 1 | 458.57 | 2.46 | .028 | .120 |
| Education Years | 1 | .28 | .00 | | .969 |
| Profession | 1 | 103.32 | .55 | | .459 |
| **Outcome: Total C** | | | | | |
| Obesity Group | 1 | 40.82 | .24 | .003 | .629 |
| Education Years | 1 | 24.13 | .14 | | .710 |
| Profession | 1 | 82.57 | .48 | | .492 |
| **Outcome: Total D** | | | | | |
| Obesity Group | 1 | 137.85 | .67 | .008 | .414 |
| Education Years | 1 | 36.14 | .18 | | .676 |
| Profession | 1 | 4.95 | .02 | | .877 |

*continued*

*Table 5 continued.*

| | df | Type III Sum of Squares | F | $\eta^2$ | *p* |
|---|---|---|---|---|---|
| **Outcome: Hot DM** | | | | | |
| Obesity Group | 1 | 1.62 | .00 | .000 | .944 |
| Education Years | 1 | 289.29 | .88 | | .351 |
| Profession | 1 | 503.35 | 1.53 | | .219 |
| **Outcome: Cold DM** | | | | | |
| Obesity Group | 1 | 862.51 | 2.13 | .024 | .148 |
| Education Years | 1 | 90.37 | .22 | | .638 |
| Profession | 1 | 12.38 | .03 | | .862 |

Note: BART=Average number of pumps adjusted for only non-exploded balloons on Balloon Analogue Risk Task, GDT=Advantageous dice throws on Game of Dice Task, DDT=Discounting of future reward on Delay Discounting Task, Total A=Percent of choices made from deck A on IGT, Total B=Percent of choices made from deck B on IGT, Total C=Percent of choices made from deck C on IGT, Total D=Percent of choices made from deck D on IGT, Hot DM=Percent of first 40 choices made from advantageous decks on IGT, Cold DM=Percent of last 60 choices made from advantageous decks on IGT.

*Table 6*. Pearson correlations of BMI, body fat, and continuous demographic variables with decision making outcomes among obese participants only (n=50).

| | BART | GDT | DDT | Total A | Total B | Total C | Total D | Hot DM | Cold DM |
|---|---|---|---|---|---|---|---|---|---|
| BMI | -0.05 | -0.15 | 0.08 | -0.03 | 0.17 | 0.03 | -0.18 | -0.09 | -0.13 |
| Body Fat | 0.06 | -0.07 | 0.08 | 0.02 | 0.17 | 0.04 | -0.21 | -0.03 | -0.19 |
| Age | -0.18 | 0.06 | -0.01 | 0.17 | 0.00 | -0.22 | 0.10 | 0.02 | -0.13 |
| Education Years | 0.01 | 0.46* | -0.12 | 0.13 | 0.07 | -0.05 | -0.09 | -0.12 | -0.10 |

Note: * $p<0.05$, BART=Average number of pumps adjusted for only non-exploded balloons on Balloon Analogue Risk Task, GDT=Advantageous dice throws on Game of Dice Task, DDT=Discounting of future reward on Delay Discounting Task, Total A=Percent of choices made from deck A on IGT, Total B=Percent of choices made from deck B on IGT, Total C=Percent of choices made from deck C on IGT, Total D=Percent of choices made from deck D on IGT, Hot DM=Percent of first 40 choices made from advantageous decks on IGT, Cold DM=Percent of last 60 choices made from advantageous decks on IGT.

*Table 7.* Mean decision making scores for categorical demographic variables among obese participants (n=50).

| | **Sex** | | **Ethnicity** | | **Marital Status** | | |
|---|---|---|---|---|---|---|---|
| | Female | Male | White | Non-white | Married | Single, Never Married | Divorced/ Separated |
| BART | 25.11 | 33.05 | 25.26 | 29.64 | 25.74 | 31.09 | 16.38 |
| GDT | 11.88 | 12.29 | 11.46 | 13.64 | 12.76 | 10.53 | 11.50 |
| DDT | 0.03 | 0.04 | 0.02 | 0.06 | 0.02 | 0.02 | 0.10[b] |
| Total A | 15.47 | 16.14 | 15.10 | 17.18 | 16.52 | 14.40 | 13.83 |
| Total B | 35.67 | 39.43 | 36.03 | 36.18 | 36.93 | 36.10 | 33.00 |
| Total C | 18.86 | 29.00 | 21.15 | 17.18 | 20.00 | 22.60 | 15.83 |
| Total D | 30.00 | 15.43[a] | 27.72 | 28.82 | 26.55 | 26.93 | 37.33 |
| Hot DM | 43.78 | 39.29 | 42.56 | 45.23 | 41.72 | 46.17 | 42.50 |
| Cold DM | 52.25 | 47.86 | 53.08 | 46.52 | 49.77 | 51.78 | 60.28 |

| | **Profession** | | **Work Status** | | |
|---|---|---|---|---|---|
| | White Collar | Blue Collar | Employed Full-Time/Part-Time | Unemployed/ Retired | Homemaker |
| BART | 26.78 | 23.69 | 27.25 | 21.04 | 26.44 |
| GDT | 12.61 | 8.89 | 12.18 | 10.25 | 14.00 |
| DDT | 0.03 | 0.02 | 0.04 | 0.01 | 0.05 |
| Total A | 15.24 | 17.00 | 14.55 | 20.38 | 16.50 |
| Total B | 35.95 | 37.33 | 37.65 | 32.13 | 23.50 |
| Total C | 20.37 | 19.89 | 19.98 | 18.63 | 33.00 |
| Total D | 28.44 | 25.78 | 27.83 | 28.88 | 27.00 |
| Hot DM | 44.51 | 36.94 | 42.75 | 45.63 | 41.25 |
| Cold DM | 51.67 | 51.48 | 51.17 | 48.75 | 72.50 |

Note: a $p<.05$, sex difference; b $p<.05$, divorced/separated different from others. BART=Average number of pumps adjusted for only non-exploded balloons on Balloon Analogue Risk Task, GDT=Advantageous dice throws on Game of Dice Task, DDT=Discounting of future reward on Delay Discounting Task, Total A=Percent of choices made from deck A on IGT, Total B=Percent of choices made from deck B on IGT, Total C=Percent of choices made from deck C on IGT, Total D=Percent of choices made from deck D on IGT, Hot DM=Percent of first 40 choices made from advantageous decks on IGT, Cold DM=Percent of last 60 choices made from advantageous decks on IGT.

*Table 8.* Pearson correlations of BMI and body fat with decision making outcomes among the full sample (n=90).

| | BART | GDT | DDT | Total A | Total B | Total C | Total D | Hot DM | Cold DM |
|---|---|---|---|---|---|---|---|---|---|
| BMI | -0.02 | -0.09 | 0.19 | -0.04 | 0.21* | -0.04 | -0.14 | 0.04 | -0.24* |

Note: * $p<0.05$, BART=Average number of pumps adjusted for only non-exploded balloons on Balloon Analogue Risk Task, GDT=Advantageous dice throws on Game of Dice Task, DDT=Discounting of future reward on Delay Discounting Task, Total A=Percent of choices made from deck A on IGT, Total B=Percent of choices made from deck B on IGT, Total C=Percent of choices made from deck C on IGT, Total D=Percent of choices made from deck D on IGT, Hot DM=Percent of first 40 choices made from advantageous decks on IGT, Cold DM=Percent of last 60 choices made from advantageous decks on IGT.

*Table 9.* Bootstrapped mediation analyses evaluating distance walked as a mediator in the relationship between BMI and decision making outcomes among obese participants (n=50)

| | **Parameter Estimates** | **Standard Errors** | ***t*** | **Bootstrapped Confidence Interval (95%)** |
|---|---|---|---|---|
| **Outcome: BART** | | | | |
| A: BMI > Distance Walked | -19.96 | 3.74 | -5.34 | (-27.4843, -12.4345) |
| B: Distance Walked > BART | .01 | .01 | .86 | (-.0112, .0280) |
| C': BMI > BART | .07 | .31 | .23 | (-.5615, .7042) |
| C: Total Model | -.10 | .25 | -.39 | (-.5912, .3999) |
| AB: Mediating Pathway | -.17 | .19 | | (-.6035, .1545) |
| **Outcome: GDT** (controlling for education years) | | | | |
| A: BMI > Distance Walked | -19.34 | 3.92 | -4.94 | (-27.2280, -11.4560) |
| B: Distance Walked > GDT | .00 | .00 | -.08 | (-.0061, .0056) |
| C': BMI > GDT | -.02 | .09 | -.24 | (-.2137, .1686) |
| C: Total Model | -.02 | .08 | -.24 | (-.1704, .1338) |
| AB: Mediating Pathway | .00 | .05 | | (-.0844, .0996) |
| **Outcome: DDT** (controlling for marital status) | | | | |
| A: BMI > Distance Walked | -20.24 | 3.49 | -5.80 | (-27.2660, -13.2063) |
| B: Distance Walked > DDT | .00 | .00 | .04 | (-.0001, .0001) |
| C': BMI > DDT | .00 | .00 | .44 | (-.0017, .0026) |
| C: Total Model | .00 | .00 | .55 | (-.0012, .0021) |
| AB: Mediating Pathway | .00 | .00 | | (-.0013, .0016) |
| **Outcome: Total A** | | | | |
| A: BMI > Distance Walked | -19.96 | 3.74 | -5.34 | (-27.4843, -12.4345) |
| B: Distance Walked > Total A | -.01 | .00 | -1.79 | (-.0184, .0011) |
| C': BMI > Total A | -.21 | .16 | -1.32 | (-.5207, .1080) |
| C: Total Model | -.03 | .13 | -.26 | (-.2859, .2195) |
| AB: Mediating Pathway | -.17 | .10 | | (.0049, .4265)* |
| **Outcome: Total B** | | | | |
| A: BMI > Distance Walked | -19.96 | 3.74 | -5.34 | (-27.4843, -12.4345) |
| B: Distance Walked > Total B | .01 | .01 | 1.00 | (-.0090, .0266) |
| C': BMI > Total B | .44 | .29 | 1.53 | (-.1389, 1.0105) |
| C: Total Model | .26 | .22 | 1.16 | (-.1917, .7109) |
| AB: Mediating Pathway | -.18 | .17 | | (-.5363, .1350) |

*continued*

*Table 9 continued.*

| | Parameter Estimates | Standard Errors | *t* | Bootstrapped Confidence Interval (95%) |
|---|---|---|---|---|
| **Outcome: Total C** | | | | |
| A: BMI > Distance Walked | -19.96 | 3.74 | -5.34 | (-27.4843, -12.4345) |
| B: Distance Walked > Total C | .02 | .01 | 1.87 | (-.0012, .0313) |
| C': BMI > Total C | .35 | .26 | 1.35 | (-.1738, .8752) |
| C: Total Model | .05 | .21 | .24 | (-.3733, .4725) |
| AB: Mediating Pathway | -.30 | .17 | | (-.6809, -.0173)* |
| **Outcome: Total D** (controlling for gender) | | | | |
| A: BMI > Distance Walked | -19.27 | 4.17 | -4.62 | (-27.6684, -10.8773) |
| B: Distance Walked > Total D | -.02 | .01 | -1.92 | (-.0335, .0008) |
| C': BMI > Total D | -.37 | .29 | -1.29 | (-.9567, .2099) |
| C: Total Model | -.06 | .25 | -.24 | (-.5523, .4358) |
| AB: Mediating Pathway | .32 | .19 | | (-.0299, .7013) |
| **Outcome: Hot DM** | | | | |
| A: BMI > Distance Walked | -19.96 | 3.74 | -5.34 | (-27.4843, -12.4345) |
| B: Distance Walked > Hot DM | .00 | .01 | -.10 | (-.0239, .0216) |
| C': BMI > Hot DM | -.19 | .36 | -.53 | (-.9256, .5400) |
| C: Total Model | -.17 | .28 | -.60 | (-.7392, .3993) |
| AB: Mediating Pathway | .02 | .21 | | (-.3547, .4788) |
| **Outcome: Cold DM** | | | | |
| A: BMI > Distance Walked | -19.96 | 3.74 | -5.34 | (-27.4843, -12.4345) |
| B: Distance Walked > Cold DM | .00 | .01 | .04 | (-.0250, .0260) |
| C': BMI > Cold DM | -.25 | .41 | -.62 | (-1.0776, .5696) |
| C: Total Model | -.26 | .32 | -.83 | (-.9037, .3757) |
| AB: Mediating Pathway | -.01 | .34 | | (-.7064, .5981) |

Note: * significant mediating effect observed, BART=Average number of pumps adjusted for only non-exploded balloons on Balloon Analogue Risk Task, GDT=Advantageous dice throws on Game of Dice Task, DDT=Discounting of future reward on Delay Discounting Task, Total A=Percent of choices made from deck A on IGT, Total B=Percent of choices made from deck B on IGT, Total C=Percent of choices made from deck C on IGT, Total D=Percent of choices made from deck D on IGT, Hot DM=Percent of first 40 choices made from advantageous decks on IGT, Cold DM=Percent of last 60 choices made from advantageous decks on IGT.

*Table 10.* Bootstrapped mediation analyses evaluating distance walked as a mediator in the relationship between body fat percentage and decision making outcomes among obese participants (n=50).

| | Parameter Estimates | Standard Errors | *t* | Bootstrapped Confidence Interval (95%) |
|---|---|---|---|---|
| **Outcome: BART** | | | | |
| A: Body Fat > Distance Walked | -15.91 | 4.33 | -3.67 | (-24.6289, -7.1831) |
| B: Distance Walked > BART | .01 | .01 | 1.20 | (-.0070, .0278) |
| C’: Body Fat > BART | .24 | .29 | .82 | (-.3440, .8191) |
| C: Total Model | .07 | .26 | .28 | (-.4412, .5861) |
| AB: Mediating Pathway | -.17 | .16 | | (-.5509, .0791) |
| **Outcome: GDT** (controlling for education years) | | | | |
| A: Body Fat > Distance Walked | -15.06 | 4.36 | -3.46 | (-23.8364, -6.2839) |
| B: Distance Walked > GDT | .00 | .00 | .05 | (-.0052, .0054) |
| C’: Body Fat > GDT | .00 | .09 | -.05 | (-.1791, .1703) |
| C: Total Model | -.01 | .08 | -.08 | (-.1598, .1471) |
| AB: Mediating Pathway | .00 | .04 | | (-.0757, .0739) |
| **Outcome: DDT** (controlling for marital status) | | | | |
| A: Body Fat > Distance Walked | -19.85 | 3.97 | -5.00 | (-27.8573, -11.8473) |
| B: Distance Walked > DDT | .00 | .00 | .04 | (-.0001, .0001) |
| C’: Body Fat > DDT | .00 | .00 | 1.15 | (-.0009, .0034) |
| C: Total Model | .00 | .00 | 1.13 | (-.0008, .0027) |
| AB: Mediating Pathway | .00 | .00 | | (-.0015, .0008) |
| **Outcome: Total A** | | | | |
| A: Body Fat > Distance Walked | -15.91 | 4.33 | -3.67 | (-24.6289, -7.1831) |
| B: Distance Walked > Total A | .00 | .00 | -1.33 | (-.0147, .0030) |
| C’: Body Fat > Total A | -.08 | .15 | -.54 | (-.3753, .2156) |
| C: Total Model | .01 | .13 | .10 | (-.2486, .2752) |
| AB: Mediating Pathway | .09 | .08 | | (-.0205, .2923) |
| **Outcome: Total B** | | | | |
| A: Body Fat > Distance Walked | -15.91 | 4.33 | -3.67 | (-24.6289, -7.1831) |
| B: Distance Walked > Total B | .01 | .01 | .70 | (-.0105, .0215) |
| C’: Body Fat > Total B | .36 | .27 | 1.34 | (-.1791, .8905) |
| C: Total Model | .27 | .23 | 1.15 | (-.1999, .7350) |
| AB: Mediating Pathway | -.09 | .12 | | (-.3676, .1224) |

*continued*

*Table 10 continued.*

| | Parameter Estimates | Standard Errors | *t* | Bootstrapped Confidence Interval (95%) |
|---|---|---|---|---|
| **Outcome: Total C** | | | | |
| A: Body Fat > Distance Walked | -15.91 | 4.33 | -3.67 | (-24.6289, -7.1831) |
| B: Distance Walked > Total C | .01 | .01 | 1.64 | (-.0027, .0266) |
| C': Body Fat > Total C | .25 | .24 | 1.03 | (-.2397, .7389) |
| C: Total Model | .06 | .22 | .28 | (-.3778, .4980) |
| AB: Mediating Pathway | -.19 | .12 | | (-.4769, -.0230)* |
| **Outcome: Total D** (controlling for gender) | | | | |
| A: Body Fat > Distance Walked | -15.36 | 5.49 | -2.80 | (-26.4058, -4.3110) |
| B: Distance Walked > Total D | -.01 | .01 | -1.55 | (-.0275, .0036) |
| C': Body Fat > Total D | -.19 | .31 | -.63 | (-.8132, .4262) |
| C: Total Model | -.01 | .29 | -.03 | (-.5899, .5709) |
| AB: Mediating Pathway | .18 | .17 | | (-.0536, .5909) |
| **Outcome: Hot DM** | | | | |
| A: Body Fat > Distance Walked | -15.91 | 4.33 | -3.67 | (-24.6289, -7.1831) |
| B: Distance Walked > Hot DM | .00 | .01 | .21 | (-.0182, .0225) |
| C': Body Fat > Hot DM | -.03 | .34 | -.09 | (-.7111, .6491) |
| C: Total Model | -.06 | .29 | -.22 | (-.6561, .5270) |
| AB: Mediating Pathway | -.03 | .17 | | (-.3665, .3101) |
| **Outcome: Cold DM** | | | | |
| A: Body Fat > Distance Walked | -15.91 | 4.33 | -3.67 | (-24.6289, -7.1831) |
| B: Distance Walked > Cold DM | .00 | .01 | -.08 | (-.0234, .0217) |
| C': Body Fat > Cold DM | -.44 | .37 | -1.17 | (-1.1930, .3148) |
| C: Total Model | -.43 | .33 | -1.31 | (-1.0805, .2304) |
| AB: Mediating Pathway | .01 | .22 | | (-.4509, .4474) |

Note: * significant mediating effect observed, BART=Average number of pumps adjusted for only non-exploded balloons on Balloon Analogue Risk Task, GDT=Advantageous dice throws on Game of Dice Task, DDT=Discounting of future reward on Delay Discounting Task, Total A=Percent of choices made from deck A on IGT, Total B=Percent of choices made from deck B on IGT, Total C=Percent of choices made from deck C on IGT, Total D=Percent of choices made from deck D on IGT, Hot DM=Percent of first 40 choices made from advantageous decks on IGT, Cold DM=Percent of last 60 choices made from advantageous decks on IGT.

*Table 11*. Moderation analyses evaluating distance walked as a moderator in the relationship between BMI and balloon analogue risk task performance among obese participants (n=50).

**Dependent Variable: BART**

$R^2$ = .034, *MSE* = 273.90

| Predictors | Coefficient | Standard Errors | *t* | *p* |
|---|---|---|---|---|
| Intercept | -13.23 | 42.04 | -.31 | .754 |
| Distance Walked | .04 | .04 | .98 | .333 |
| BMI | .62 | .75 | .83 | .412 |
| Distance Walked x BMI | .00 | .00 | -.81 | .424 |

R-square increase due to interaction = .014, *F* (1,46) = .65

**Conditional effects of BMI on BART at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | .25 | .38 | .64 | .523 | (-.5248, 1.0171) |
| 865.13 | .03 | .32 | .11 | .914 | (-.6075, .6770) |
| 1179.41 | -.18 | .44 | -.40 | .690 | (-1.0636, .7104) |

*Table 12.* Moderation analyses evaluating distance walked as a moderator in the relationship between BMI and game of dice task performance among obese participants (n=50).

**Dependent Variable: GDT** (controlling for education years)

$R^2$ = .279, *MSE* = 22.85

| Predictors | Coefficient | Standard Errors | *T* | *p* |
|---|---|---|---|---|
| Intercept | 17.00 | 13.84 | 1.23 | .226 |
| Distance Walked | -.02 | .01 | -1.80 | .079 |
| BMI | -.38 | .22 | -1.76 | .086 |
| Distance Walked x BMI | .00 | .00 | 1.83 | .075 |
| Education | 1.04 | .33 | 3.19 | .003 |

R-square increase due to interaction = .056, *F* (1,45) = 3.34

**Conditional effects of BMI on GDT at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | -.14 | .11 | -1.25 | .22 | (-.3684, .0867) |
| 865.13 | .00 | .09 | -.02 | .98 | (-.1896, .1860) |
| 1179.41 | .14 | .13 | 1.08 | .29 | (-.1194, .3938) |

*Table 13.* Moderation analyses evaluating distance walked as a moderator in the relationship between BMI and delay discounting task performance among obese participants (n=50).

**Dependent Variable: DDT** (controlling for marital status)

$R^2$ = .122, *MSE* = .00

| Predictors | Coefficient | Standard Errors | *t* | *p* |
|---|---|---|---|---|
| Intercept | -.01 | .15 | -.09 | .927 |
| Distance Walked | .00 | .00 | -.23 | .819 |
| BMI | .00 | .00 | -.03 | .973 |
| Distance Walked x BMI | .00 | .00 | .25 | .806 |
| Marital Status | .03 | .01 | 2.19 | .034 |

R-square increase due to interaction = .001, $F$ (1,45) = .061

**Conditional effects of BMI on DDT at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | .00 | .00 | .22 | .825 | (-.0023, .0029) |
| 865.13 | .00 | .00 | .46 | .646 | (-.0017, .0027) |
| 1179.41 | .00 | .00 | .49 | .628 | (-.0022, .0037) |

*Table 14*. Moderation analyses evaluating distance walked as a moderator in the relationship between BMI and percentage of selections from deck A on the IGT among obese participants (n=50).

**Dependent Variable: Total A**

$R^2$ = .070, *MSE* = 68.44

| Predictors | Coefficient | Standard Errors | *t* | *p* |
|---|---|---|---|---|
| Intercept | 27.19 | 21.01 | 1.29 | .202 |
| Distance Walked | .00 | .02 | -.10 | .917 |
| BMI | -.11 | .37 | -.28 | .780 |
| Distance Walked x BMI | .00 | .00 | -.30 | .765 |
| R-square increase due to interaction = .002, *F* (1,46) = .09 | | | | |

**Conditional effects of BMI on Total A at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | -.17 | .19 | -.91 | .368 | (-.5592, .2115) |
| 865.13 | -.21 | .16 | -1.34 | .188 | (-.5341, .1079) |
| 1179.41 | -.25 | .22 | -1.15 | .258 | (-.6957, .1910) |

*Table 15*. Moderation analyses evaluating distance walked as a moderator in the relationship between BMI and percentage of selections from deck B on the IGT among obese participants (n=50).

**Dependent Variable: Total B**

$R^2$ = .069, *MSE* = 224.46

| Predictors | Coefficient | Standard Errors | *t* | *p* |
|---|---|---|---|---|
| Intercept | -23.42 | 38.05 | -.62 | .541 |
| Distance Walked | .05 | .04 | 1.16 | .251 |
| BMI | 1.02 | .67 | 1.52 | .136 |
| Distance Walked x BMI | .00 | .00 | -.96 | .340 |

R-square increase due to interaction = .020, *F* (1,46) = .93

**Conditional effects of BMI on Total B at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | .62 | .35 | 1.80 | .078 | (-.0733, 1.3225) |
| 865.13 | .40 | .29 | 1.37 | .177 | (-.1851, .9777) |
| 1179.41 | .17 | .40 | .42 | .68 | (-.6349, .9709) |

*Table 16.* Moderation analyses evaluating distance walked as a moderator in the relationship between BMI and percentage of selections from deck C on the IGT among obese participants (n=50).

| **Dependent Variable: Total C** | | | | |
|---|---|---|---|---|
| $R^2$ = .093, *MSE* = 186.80 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | 20.23 | 34.72 | .58 | .563 |
| Distance Walked | -.02 | .04 | -.54 | .591 |
| BMI | -.20 | .62 | -.32 | .749 |
| Distance Walked x BMI | .00 | .00 | .98 | .330 |
| R-square increase due to interaction = .020, *F* (1,46) = .97 | | | | |

**Conditional effects of BMI on Total C at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | .17 | .32 | .55 | .583 | (-.4619, .8114) |
| 865.13 | .39 | .26 | 1.47 | .148 | (-.1429, .9179) |
| 1179.41 | .60 | .36 | 1.65 | .106 | (-.1323, 1.3327) |

*Table 17.* Moderation analyses evaluating distance walked as a moderator in the relationship between BMI and percentage of selections from deck D on the IGT among obese participants (n=50).

| **Dependent Variable: Total D** (controlling for gender) | | | | |
|---|---|---|---|---|
| $R^2$ = .185, *MSE* = 212.17 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | 37.72 | 40.80 | .92 | .360 |
| Distance Walked | -.02 | .04 | -.59 | .561 |
| BMI | -.47 | .67 | -.71 | .482 |
| Distance Walked x BMI | .00 | .00 | .17 | .870 |
| Gender | 14.68 | 6.60 | 2.23 | .031 |
| R-square increase due to interaction = .001, *F* (1,45) = .03 | | | | |

**Conditional effects of BMI on Total D at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | -.41 | .35 | -1.16 | .254 | (-1.1130, .3023) |
| 865.13 | -.37 | .30 | 1.25 | .220 | (-.9622, .2276) |
| 1179.41 | -.33 | .40 | -.83 | .411 | (-1.1285, .4699) |

*Table 18.* Moderation analyses evaluating distance walked as a moderator in the relationship between BMI and hot decision making on the IGT among obese participants (n=50).

**Dependent Variable: Hot DM**

$R^2$ = .009, *MSE* = 372.34

| Predictors | Coefficient | Standard Errors | *T* | *p* |
|---|---|---|---|---|
| Intercept | 61.85 | 49.01 | 1.26 | .214 |
| Distance Walked | -.01 | .05 | -.22 | .825 |
| BMI | -.35 | .87 | -.41 | .685 |
| Distance Walked x BMI | .00 | .00 | .21 | .838 |

R-square increase due to interaction = .001, *F* (1,46) = .04

**Conditional effects of BMI on Hot DM at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | -.24 | .45 | -.55 | .586 | (-1.1434, .6543) |
| 865.13 | -.18 | .37 | -.49 | .627 | (-.9308, .5669) |
| 1179.41 | -.12 | .51 | -.23 | .817 | (-1.1535, .9148) |

*Table 19.* Moderation analyses evaluating distance walked as a moderator in the relationship between BMI and cold decision making on the IGT among obese participants (n=50).

| **Dependent Variable: Cold DM** | | | | |
|---|---|---|---|---|
| $R^2$ = .046, *MSE* = 455.90 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | 119.16 | 54.23 | 2.20 | .033 |
| Distance Walked | -.07 | .06 | -1.16 | .253 |
| BMI | -1.30 | .96 | -1.35 | .184 |
| Distance Walked x BMI | .00 | .00 | 1.20 | .238 |
| R-square increase due to interaction = .031, *F* (1,46) = 1.43 | | | | |

| **Conditional effects of BMI on Cold DM at the mean and ± 1 SD from the mean of Distance Walked** | | | | | |
|---|---|---|---|---|---|
| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
| 550.84 | -.59 | .49 | -1.19 | .240 | (-1.5829, .4063) |
| 865.13 | -.18 | .41 | -.45 | .657 | (-1.0126, .6445) |
| 1179.41 | .22 | .57 | .39 | .700 | (-.9241, 1.3645) |

*Table 20.* Moderation analyses evaluating distance walked as a moderator in the relationship between body fat percentage and balloon analogue risk task performance among obese participants (n=50).

| **Dependent Variable: BART** | | | | |
|---|---|---|---|---|
| $R^2$ = .033, *MSE* = 274.09 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | 8.86 | 39.89 | .22 | .825 |
| Distance Walked | .01 | .04 | .14 | .891 |
| Body Fat | .18 | .67 | .26 | .795 |
| Distance Walked x Body Fat | .00 | .00 | .10 | .918 |
| R-square increase due to interaction = .000, *F* (1,46) = .01 | | | | |

**Conditional effects of Body Fat on BART at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | .22 | .34 | .64 | .524 | (-.4691, .9076) |
| 865.13 | .24 | .30 | .82 | .419 | (-.3588, .8475) |
| 1179.41 | .27 | .42 | .63 | .529 | (-.5867, 1.1258) |

*Table 21.* Moderation analyses evaluating distance walked as a moderator in the relationship between body fat percentage and game of dice task performance among obese participants (n=50).

| **Dependent Variable: GDT** (controlling for education years) | | | | |
|---|---|---|---|---|
| $R^2$ = .224, *MSE* = 24.61 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | -1.90 | 12.77 | -.15 | .883 |
| Distance Walked | .00 | .01 | -.26 | .794 |
| Body Fat | -.05 | .20 | -.27 | .787 |
| Distance Walked x Body Fat | .00 | .00 | .28 | .782 |
| Education | 1.12 | .33 | 3.39 | .002 |
| R-square increase due to interaction = .001, *F* (1,45) = .08 | | | | |

| **Conditional effects of Body Fat on GDT at the mean and ± 1 SD from the mean of Distance Walked** | | | | | |
|---|---|---|---|---|---|
| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
| 550.84 | -.02 | .10 | -.19 | .853 | (-.2256, .1873) |
| 865.13 | .00 | .09 | .01 | .990 | (-.1800, .1822) |
| 1179.41 | .02 | .13 | .17 | .868 | (-.2358, .2785) |

*Table 22.* Moderation analyses evaluating distance walked as a moderator in the relationship between body fat percentage and delay discounting task performance among obese participants (n=50).

| **Dependent Variable: DDT** (controlling for marital status) | | | | |
|---|---|---|---|---|
| $R^2$ = .147, *MSE* = .003 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | -.05 | .15 | -.35 | .728 |
| Distance Walked | .00 | .00 | -.35 | .727 |
| Body Fat | .00 | .00 | .13 | .895 |
| Distance Walked x Body Fat | .00 | .00 | .46 | .650 |
| Marital Status | .04 | .01 | 2.42 | .020 |
| R-square increase due to interaction = .004, *F* (1,45) = .21 | | | | |

**Conditional effects of Body Fat on DDT at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | .00 | .00 | .75 | .457 | (-.0016, .0035) |
| 865.13 | .00 | .00 | 1.20 | .239 | (-.0009, .0035) |
| 1179.41 | .00 | .00 | 1.16 | .253 | (-.0012, .0046) |

*Table 23.* Moderation analyses evaluating distance walked as a moderator in the relationship between body fat percentage and percentage of selections from deck A on the IGT among obese participants (n=50).

**Dependent Variable: Total A**

$R^2$ = .050, *MSE* = 69.96

| Predictors | Coefficient | Standard Errors | *t* | *p* |
|---|---|---|---|---|
| Intercept | 12.09 | 20.15 | .60 | .552 |
| Distance Walked | .01 | .02 | .44 | .661 |
| Body Fat | .14 | .34 | .41 | .681 |
| Distance Walked x Body Fat | .00 | .00 | -.72 | .474 |

R-square increase due to interaction = .011, *F* (1,46) = .52

**Conditional effects of Body Fat on Total A at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | -.02 | .17 | -.09 | .930 | (-.3629, .3325) |
| 865.13 | -.10 | .15 | -.69 | .496 | (-.4085, .2008) |
| 1179.41 | -.19 | .21 | -.90 | .375 | (-.6251, .2400) |

*Table 24.* Moderation analyses evaluating distance walked as a moderator in the relationship between body fat percentage and percentage of selections from deck B on the IGT among obese participants (n=50).

| **Dependent Variable: Total B** | | | | |
|---|---|---|---|---|
| $R^2$ = .039, *MSE* = 231.70 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | 18.04 | 36.67 | .49 | .625 |
| Distance Walked | .00 | .04 | -.02 | .986 |
| Body Fat | .27 | .62 | .43 | .666 |
| Distance Walked x Body Fat | .00 | .00 | .16 | .874 |
| R-square increase due to interaction = .001, *F* (1,46) = .03 | | | | |

| **Conditional effects of Body Fat on Total B at the mean and ± 1 SD from the mean of Distance Walked** | | | | | |
|---|---|---|---|---|---|
| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
| 550.84 | .33 | .31 | 1.05 | .299 | (-.3031, .9626) |
| 865.13 | .37 | .28 | 1.33 | .191 | (-.1892, .9199) |
| 1179.41 | .40 | .39 | 1.03 | .310 | (-.3864, 1.1881) |

*Table 25.* Moderation analyses evaluating distance walked as a moderator in the relationship between body fat percentage and percentage of selections from deck C on the IGT among obese participants (n=50).

| **Dependent Variable: Total C** | | | | |
|---|---|---|---|---|
| $R^2$ = .060, *MSE* = 193.55 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | 6.83 | 33.52 | .20 | .840 |
| Distance Walked | .00 | .04 | -.01 | .994 |
| Body Fat | .08 | .56 | .14 | .892 |
| Distance Walked x Body Fat | .00 | .00 | .34 | .735 |
| R-square increase due to interaction = .003, *F* (1,46) = .12 | | | | |

**Conditional effects of Body Fat on Total C at the mean and ± 1 SD from the mean of Distance Walked**

| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
|---|---|---|---|---|---|
| 550.84 | .19 | .29 | .69 | .492 | (-.3796, .7773) |
| 865.13 | .27 | .25 | 1.07 | .292 | (-.2384, .7753) |
| 1179.41 | .34 | .36 | .95 | .349 | (-.3814, 1.0577) |

*Table 26.* Moderation analyses evaluating distance walked as a moderator in the relationship between body fat percentage and percentage of selections from deck D on the IGT among obese participants (n=50).

| **Dependent Variable: Total D** (controlling for gender) | | | | |
|---|---|---|---|---|
| $R^2$ = .166, *MSE* = 217.17 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | 3.38 | 46.19 | .07 | .942 |
| Distance Walked | .01 | .04 | .17 | .863 |
| Body Fat | .09 | .66 | .14 | .891 |
| Distance Walked x Body Fat | .00 | .00 | -.49 | .628 |
| Gender | 15.57 | 7.71 | 2.02 | .050 |
| R-square increase due to interaction = .005, *F* (1,45) = .24 | | | | |

| **Conditional effects of Body Fat on Total D at the mean and ± 1 SD from the mean of Distance Walked** | | | | | |
|---|---|---|---|---|---|
| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
| 550.84 | -.10 | .37 | -.27 | .791 | (-.8382, .6427) |
| 865.13 | -.21 | .31 | -.66 | .513 | (-.8329, .4221) |
| 1179.41 | -.31 | .40 | -.79 | .433 | (-1.1106, .4845) |

*Table 27.* Moderation analyses evaluating distance walked as a moderator in the relationship between body fat percentage and hot decision making performance on the IGT among obese participants (n=50).

| **Dependent Variable: Hot DM** | | | | |
|---|---|---|---|---|
| $R^2$ = ..009, *MSE* = 372.32 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | 20.52 | 46.49 | .44 | .661 |
| Distance Walked | .03 | .05 | .59 | .560 |
| Body Fat | .36 | .78 | .46 | .646 |
| Distance Walked x Body Fat | .00 | .00 | -.56 | .580 |
| R-square increase due to interaction = .007, *F* (1,46) = .31 | | | | |

| **Conditional effects of Body Fat on Hot DM at the mean and ± 1 SD from the mean of Distance Walked** | | | | | |
|---|---|---|---|---|---|
| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
| 550.84 | .08 | .40 | .21 | .834 | (-.7181, .8864) |
| 865.13 | -.07 | .35 | -.21 | .834 | (-.7767, .6293) |
| 1179.41 | -.23 | .50 | -.47 | .642 | (-1.2296, .7664) |

*Table 28.* Moderation analyses evaluating distance walked as a moderator in the relationship between body fat percentage and cold decision making performance on the IGT among obese participants (n=50).

| **Dependent Variable: Cold DM** | | | | |
|---|---|---|---|---|
| $R^2$ = .044, *MSE* = 456.74 | | | | |
| Predictors | Coefficient | Standard Errors | *t* | *p* |
| Intercept | 102.77 | 51.49 | 2.00 | .052 |
| Distance Walked | -.03 | .06 | -.62 | .538 |
| Body Fat | -.92 | .86 | -1.06 | .293 |
| Distance Walked x Body Fat | .00 | .00 | .62 | .540 |
| R-square increase due to interaction = .008, *F* (1,46) = .38 | | | | |

| **Conditional effects of Body Fat on Cold DM at the mean and ± 1 SD from the mean of Distance Walked** | | | | | |
|---|---|---|---|---|---|
| Distance Walked | Effect | Standard Errors | *t* | *p* | Confidence Interval (95%) |
| 550.84 | -.58 | .44 | -1.32 | .195 | (-1.4690, .3081) |
| 865.13 | -.39 | .39 | -1.00 | .322 | (-1.1653, .3920) |
| 1179.41 | -.19 | .55 | -.35 | .727 | (-1.2982, .9125) |

Appendix B: Figures

*Figure 1*. Mediation model demonstrating the indirect effect of BMI on percentage of total selection from deck A on the IGT through distance walked for obese participants only (n=50).

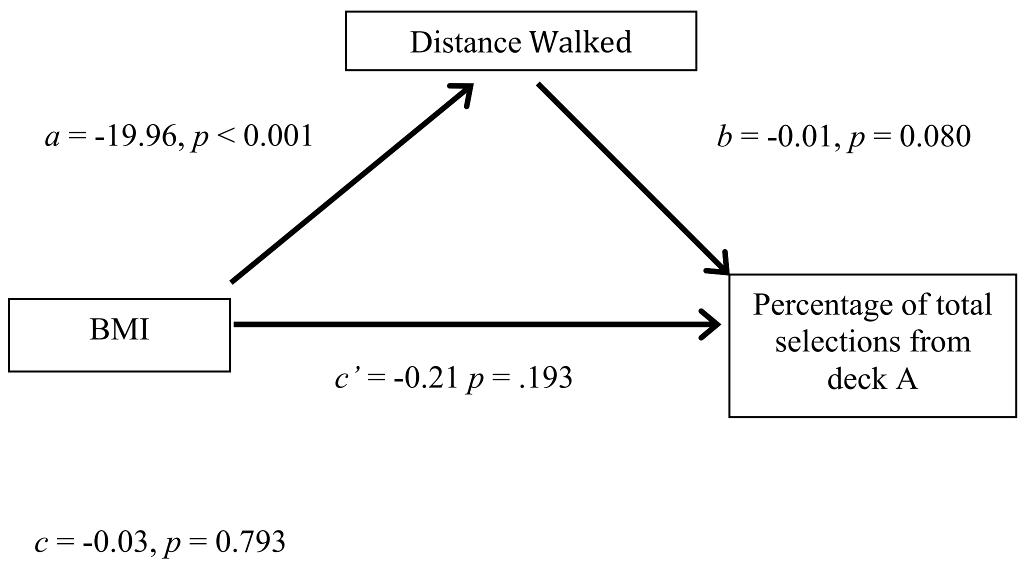


*Figure 2*. Mediation model demonstrating the indirect effect of BMI on percentage of total selection from deck C on the IGT through distance walked for obese participants only (n=50).

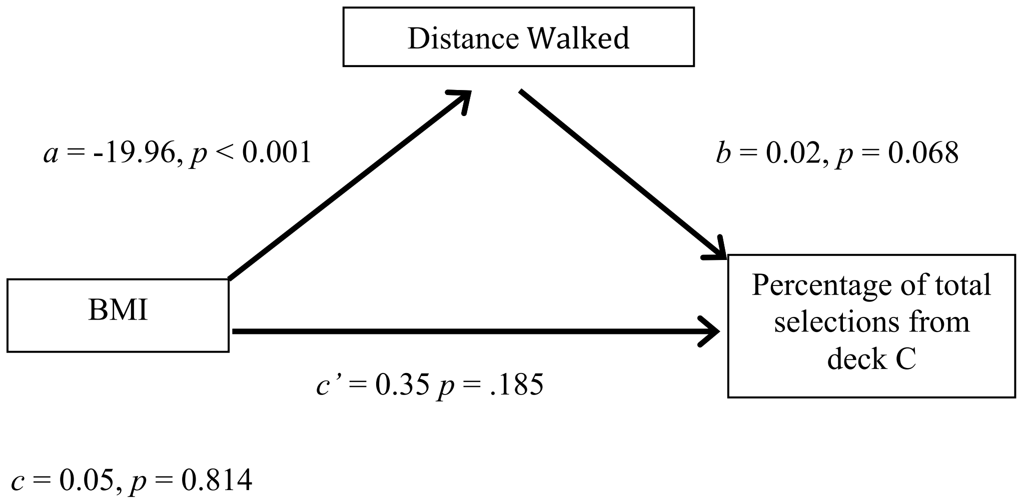
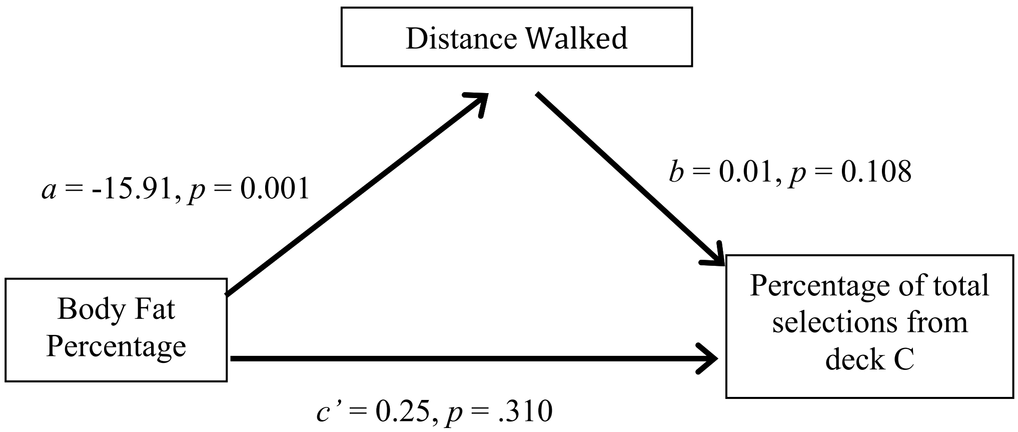


*Figure 3*. Mediation model demonstrating the indirect effect of body fat on percentage of total selection from deck C on the IGT through distance walked for obese participants only (n=50).




$c$ = 0.06, $p$ = 0.784

Appendix C: Questionnaires

*Questionnaire 1.* Participant information (demographics) form

Please circle one response for each of the questions below:

1. **With which ethnic/racial group do you primarily identify?**
    a. Black
    b. White
    c. Hispanic
    d. Asian
    e. American Indian
    f. Other (please list) ___________________________

2. **What is your gender?**
    a. Male
    b. Female
    c. Other (please list) ____________________

3. **What is your marital status?**
    a. Single, never married
    b. Married
    c. Divorced / separated
    d. Widowed

4. **What is your current work status?**
    a. Employed full-time
    b. Employed part-time
    c. Unemployed, on disability
    d. Unemployed, looking for a job
    e. Unemployed, not looking for a job
    f. Retired
    g. Homemaker, not employed outside the home

5. **Which of the following professional areas best describes your primary occupation or former occupation?**

    a. Higher executives, major professionals, owners of large businesses (less than 1000 employees)

    b. Managers of medium sized businesses (less than 500 employees), nurses, opticians, pharmacists, social workers, teachers

c. Administrative personnel, managers, minor professionals, owners/proprietors of small businesses (less than 250 employees): bakery, car dealership, engraving business, plumbing business, florist, decorator, actor, reporter, travel agent

d. Clerical and sales, technicians, bank teller, bookkeeper, clerk, draftsperson, timekeeper, secretary

e. Skilled manual - usually having had training (baker, barber, brakeperson, chef, electrician, fireperson, lineperson, machinist, mechanic, paperhanger, painter, repairperson, tailor, welder, policeperson, plumber)

f. Semi-skilled (hospital aide, painter, bartender, bus driver, cutter, cook, drill press, garage guard, checker, waiter, spot welder, machine operator)

g. Unskilled (attendant, janitor, construction helper, unspecified labor, porter).

h. Homemaker.

i. Student, disabled, no occupation.

**6. How much education have you received**

a. Less than 9 grades
   Through what grade did you complete? ___________________
b. Some high school
   Through what grade did you complete? ___________________
c. Graduated from high school
d. Trade school
e. Some college (including completion of junior college)
   How many years did you complete? _______________________
f. Graduated from a 4-year college
g. Post-graduate work at a University
   How many years did you complete? _______________________

**7. What is the highest degree you earned?**

a. High school diploma or equivalency (GED)
b. Associate degree
c. Bachelor's degree

d. Master's degree
e. Doctorate
f. Professional (MD, JD, DDS, etc.)
g. Other ______________________
h. None of the above (less than high school)

**8. What health problem(s) have you ever had? (Please check all that apply)**

| Condition | Yes, currently | Yes, but not currently | No, never |
|---|---|---|---|
| Stroke / TIA | ☐ | ☐ | ☐ |
| Heart Attack | ☐ | ☐ | ☐ |
| Angina (cardiac chest pain) | ☐ | ☐ | ☐ |
| Heart Failure | ☐ | ☐ | ☐ |
| Heart Valve disease | ☐ | ☐ | ☐ |
| Other Heart Disease | ☐ | ☐ | ☐ |
| Peripheral vascular disease | ☐ | ☐ | ☐ |
| Diabetes | ☐ | ☐ | ☐ |
| High Cholesterol | ☐ | ☐ | ☐ |
| Hypertension (high blood pressure) | ☐ | ☐ | ☐ |
| Kidney Disease | ☐ | ☐ | ☐ |
| Cancer | ☐ | ☐ | ☐ |
| Arthritis | ☐ | ☐ | ☐ |
| Chronic Obstructive Pulmonary Disease | ☐ | ☐ | ☐ |
| Lung Disease (other than COPD) | ☐ | ☐ | ☐ |
| Osteoporosis | ☐ | ☐ | ☐ |
| Depression | ☐ | ☐ | ☐ |
| **Condition** | **Yes, currently** | **Yes, but not currently** | **No, never** |
| Sleep Apnea | ☐ | ☐ | ☐ |
| Asthma | ☐ | ☐ | ☐ |
| Liver disease | ☐ | ☐ | ☐ |
| Ulcer disease | ☐ | ☐ | ☐ |
| Joint or muscle pain | ☐ | ☐ | ☐ |
| Brain/nervous system problems | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| Digestive problems | ☐ | ☐ | ☐ |
| Eye disease | ☐ | ☐ | ☐ |
| Hormonal imbalance | ☐ | ☐ | ☐ |
| Thyroid disease | ☐ | ☐ | ☐ |
| Sleep disorders (not sleep apnea) | ☐ | ☐ | ☐ |
| Chronic headaches | ☐ | ☐ | ☐ |
| Skin irritation | ☐ | ☐ | ☐ |
| Blood disorders | ☐ | ☐ | ☐ |
| Muscular Disorder (MS, post-polio) | ☐ | ☐ | ☐ |

**9. Please list all prescription and over-the-counter medications (include vitamin and mineral supplements) that you currently take.**

| | **Medication/supplement name** | **Dosage** |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

**10. Circle the letter of the statement that best describes you. "During the past 6 months my weight has…"**

a. Decreased more than 10lbs or more
b. Decreased by 5-10 lbs.
c. Been relatively stable
d. Increased by 5 to 10lbs.
e. Increased by more than 10lbs. or more.
f. I am not sure

**11. Are you currently trying to lose weight? (Circle one.)** YES

NO

**If YES,**

a. How long have you been trying to lose weight?_________-
________________________

b. Please describe any changes you've made to your dietary intake to lose weight (e.g. portion size, types of foods, commercial weight loss plan)
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
________________________________________________________

c. Please describe any changes you've made to your activity level to lose weight (e.g. exercise, parking car farther away, etc.)
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
________________________________________________________