OUTCOMES OF INCREASING PHYSICAL ACTIVITY IN OBESE POPULATIONS: WEIGHT LOSS OR COMPENSATORY SEDENTARY BEHAVIOR?

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To my grandmère, for your infinite love and encouragement…and your genes
Je t'aime, Je t'adore

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The role of physical activity in the management of obesity represents an area of debate. Concerns center on (a) whether obese individuals can achieve the amounts of moderate intensity activity necessary to affect weight loss and (b) whether high intensity activity might result in an increase in compensatory sedentary behavior. This study examined these issues in the context of a weight-loss program for obese individuals in rural communities. Participants were 181 adults with a mean ± SD age of 53.8 ± 10.5 years and body mass index of 35.6 ± 3.3 kg/m^2. Body weights were measured with a digital scale at baseline and after 6 months of weight management training. The program focused on reducing caloric intake and increasing physical activity. Physical activity was assessed over two 7-day periods during Months 0 and 6 with an electronic device that calculates energy expenditure using triaxial accelerometry, galvanic skin response, skin temperature, and heat flux (SenseWear® WMS Armband). Participants lost an average of 10.0% body weight over the course of the 6-month period (SD = 6.39). They increased physical activity of moderate intensity or greater by an average of 50.8 minutes per week (SD = 189.2). Increases in moderate intensity activity were associated with decreases in body weight, $\beta = -.197$, $t(172) = -2.72$, $p = .007$. Similarly, increasing high intensity activity was associated with weight

loss, β = -.210, t(172) = -2.91, $p = .004$, and there was no evidence that participants compensated for engaging in high intensity activity by increasing sedentary behavior at month 0 or month 6 ($p = .853$ and $p = .075$, respectively). Increasing moderate and high intensity physical activity were associated with weight loss and high intensity activity did not trigger compensatory sedentary behavior, thus increasing the intensity of physical activity may have a role in weight management lifestyle interventions.

CHAPTER 1
INTRODUCTION
Obesity

Overview

Due to the increasing prevalence of obesity in the United States, many efforts have been made to aid individuals in weight loss and maintenance. Weight loss interventions are generally focused on addressing obesity through increasing energy expenditure and/or decreasing energy intake. This study sought to assess the association between adding physical activity of varying intensities and weight loss. In addition, due to concerns that physical activity of higher intensities can trigger compensatory behavior, the presence of increased sedentary behavior following vigorous intensity physical activity was also assessed.

Prevalence and Health Risks

Obesity is a rapidly growing health concern in the United States as more than one-third of adults are classified as obese (Flegal, Carroll, Kit, & Ogden, 2012). Obesity is defined by Body Mass Index (BMI) – a measurement which is calculated based on a person's height and weight. An individual with a BMI of 30 kg/m^2 or greater is classified as obese with further designations to identify levels of obesity. Being overweight (BMI = 25.5 to 29.9 kg/m^2) or obese is a risk factor for many illnesses including: cardiovascular disease morbidity and mortality, type 2 diabetes, dyslipidemia, stroke, liver and gallbladder disease, sleep apnea, respiratory problems, gynecological problems (e.g., abnormal menses and infertility), musculoskeletal disorders such as osteoarthritis, and endometrial, breast, and colon cancer (National Heart Lung and Blood Institute, 1998; World Health Organization, 2011). Approximately 400,000 deaths can be attributed to obesity per year (Mokdad, Marks, Stroup, & Gerberding, 2004).

Given these negative health consequences, initiatives such as Healthy People 2020 remain focused on reducing obesity (United States Department of Health and Human Services, 2012). Decreases in body weight and body fat in overweight and obese individuals have been associated with improvements in their cardiovascular disease risk factors. These include improved glucose tolerance, decreased LDL cholesterol, increased HDL cholesterol, decreased triglycerides, and decreased blood pressure (Dattilo & Kris-Etherton, 1992; Ditschuneit, Flechtner-Mors, Johnson, & Adler, 1999; Fernandez, et al., 2004; Flechtner-Mors, Ditschuneit, Johnson, Suchard, & Adler, 2000; Neter, Stam, Kok, Grobbee, & Geleijnse, 2003; Stevens, et al., 2001; Wadden, Anderson, & Foster, 1999). While guidelines from the National Heart, Lung, and Blood Institute suggest losing 10% of body weight to improve cardiovascular disease risk factors, studies have demonstrated that losing 3-9% of weight also improves these risk factors (Carels, Darby, Cacciapaglia, & Douglass, 2004; National Heart Lung and Blood Institute, 1998; Pi-Sunyer, et al., 2007).

Rural Discrepancies in Obesity

The rural population in the United States has a 28% higher prevalence of obesity as compared to suburban and urban populations (Eberhardt & Pamuk, 2004). The mechanization of many rural occupations has decreased the need for physical labor while there has been little change to the traditionally high-fat, high-calorie diet needed to sustain these physically demanding occupations (Eberhardt, Ingram, Makuc, et al., 2001). It is likely that the decrease in energy expenditure coupled with no change in energy intake has caused obesity rates to increase in these rural areas (Eberhardt & Pamuk, 2004). In addition, rural populations tend to experience higher rates of poverty as compared to urban and suburban populations which may decrease the likelihood that they can afford unprocessed, more nutritious foods. Given that these individuals face barriers to medical care, such as far driving distances, treating obesity in rural settings is an important intervention area (Eberhardt & Pamuk, 2004).

Weight Regulation

Weight maintenance occurs when the body achieves energy balance (i.e., the amount of energy consumed is equivalent to the amount of energy expended). Daily energy expenditure is comprised of a few major components. Resting metabolic rate (RMR) accounts for approximately 60 to 70% of daily energy expenditure and includes the energy required to maintain the stability of the body's internal environment (i.e., homeostasis) at rest. Increases in the resting metabolic rate can occur due to the impact of various stimuli on the body (i.e., exposure to heat or cold, consumption of food, and psychological reactions such as fear or stress). The energy required to eat and digest food (i.e., the thermic effect of food) is responsible for about 10% of daily energy expenditure. The remaining 20-30% of daily energy expenditure can be accounted for by the energy cost of voluntary and involuntary physical activity (Ravussin & Swinburn, 1993).

An energy surplus occurs when caloric intake is greater than caloric expenditure. Therefore, if people decrease physical activity and their diet remains the same, they may gain weight. Conversely, an energy deficit is obtained when an individual expends more energy than he/she consumes. In order to lose one pound of weight, an individual must create an energy deficit of 3,500 kcal. Weight loss can be achieved by decreasing energy intake, increasing energy expenditure, or a combination of both strategies.

Physical Activity

Definition of Physical Activity and Current Recommendations

Physical activity is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen, Powell, & Christenson, 1985). Therefore, physical activity can involve activities of daily living (i.e., lifestyle physical activity), such as carrying groceries or bathing, as well as planned, structured activities that are focused on "improving or maintaining physical fitness" (i.e.., exercise) (Caspersen, et al., 1985). Components of physical fitness include: cardiorespiratory endurance (i.e., aerobic fitness), muscular endurance, muscular strength, body composition, and flexibility (Caspersen, et al., 1985).

Intensity of physical activity distinguishes differential amounts of energy required to perform various activities. Moderate intensity physical activity (e.g., brisk walking, water aerobics, and bicycling less than 10 miles per hour) requires about three to six times as much energy as when an individual is at rest. Vigorous intensity activity (e.g., jogging or running, swimming laps, and bicycling 10 miles per hour or faster) requires seven times or more the amount of energy expended at rest (CDC, 2011; Sallis & Owen, 1999)

Current recommendations from the American College of Sports Medicine suggest that adults engage in at least 30 minutes of moderate intensity exercise per day for at least five days per week, 20 minutes or more of vigorous intensity exercise at least 3 days per week, or a combination of moderate and vigorous exercise that amounts to greater than 500-1000 MET minutes per week in order to achieve physical fitness and health gains (Garber, et al., 2011). An individual walking in the moderate intensity zone at 4 METs for 200 minutes per week would expend 800 MET minutes per week and fall within the recommended guidelines.

Historically, there has been emphasis on the addition of moderate intensity exercise due to beliefs that adoption and adherence would be greater than to vigorous intensity exercise (Oman & King, 1998). Sedentary individuals may find it more realistic to add walking to increase their physical activity rather than beginning to jog or perform fast-paced bicycling. In addition, obese individuals are more prone to injury, particularly to their joints from the impact to the ground associated with vigorous intensity activities such as jogging (Cooper, et al., 1998; Davis, Ettinger, Neuhaus, Cho, & Hauck, 1989; Hu, Chou, Chou, Chen, & Huang, 2009; Marks, 2007). Therefore, it may be safer for obese individuals to begin by adding low impact activities, such as walking, and advance to higher impact activities when they become fitter and have lost weight.

Rural Discrepancies in Physical Activity

Just as exercise is a subset of physical activity, physical activity can be divided into occupational and leisure-time physical activity. Occupational physical activity is any physical activity performed for the purpose of one’s job, such as hammering for a construction worker or writing on the chalkboard for a teacher. Leisure-time physical activity constitutes non-work activities that may include household tasks and transportation related physical activity, such as bicycling to a neighbor’s house (Donnelly, et al., 2009).

Leisure-time physical inactivity is 50% higher in rural populations as compared to urban and suburban populations (Eberhardt & Pamuk, 2004). Environmental issues, such as a lack of sidewalks and adequate lighting for night-time exercise, provide barriers to engaging in physical activity for people living in rural areas. Due to these safety concerns and less access to publicly available places to exercise, rural adults, particularly those with a lower SES, are less likely to be active in their leisure time (Wilcox, Castro, King, Housemann, & Brownson, 2000; Wilson, Kirtland, Ainsworth, & Addy, 2004).

Compensatory Processes

Homeostasis in the presence of varying external and internal stimuli is an important function of the human body. Regulation of physiological systems such as core temperature, blood glucose, and pH are critical for normal bodily functioning. While of these systems operate within a certain range within the human species, weight can vary greatly between individuals of the same sex, age, and height. However, the variance of weight within an individual over short periods of time (i.e., 6 to 10 weeks) is low (Adam, Bestrand, & Edholm, 1961; Khosha & Billewicz, 1964; Robinson & Watson, 1965). It seems that the body has a regulation system for weight and the system maintains a set point. Evidence for this can be found in that food restriction and overconsumption do not show commensurate levels of weight loss or weight gain, respectively, given the apparent caloric changes (Apfelbaum, Bostsarron, & Lacatis, 1971). Changes in energy expenditure may account for maintenance of the weight set point despite caloric changes (Keesey, 1993).

When an individual engages in exercise to increase their physical activity the body may compensate for that energy expenditure in one of three ways: increase energy intake by consuming more calories, adjust metabolic processes, or decrease energy expenditure through being more sedentary (N. A. King, et al., 2007). Previous studies have shown that vigorous exercise might suppress appetite 15 minutes after completing the activity, but generally exercise has little effect on short-term or long-term eating behavior (Imbeault, 1997; N. A. King, Burley, & Blundell, 1994; Pi-Sunyer, 1985; Reger & Allison, 1987). Therefore, the proposition that people always eat more to maintain an energy balance is not supported. The body compensates metabolically for physical activity by decreasing the number of calories burned at rest (RMR) after exercise (N. A. King, et al., 2007). The energy cost of activity is the amount of work (i.e., caloric energy) the body needs to perform in order to execute an activity. As the body becomes fitter, a cardiovascular adjustment may decrease the energy cost of activity over time (N. A. King, et al., 2007). The more an individual engages in a particular kind of exercise, the more efficient his/her body becomes at performing that activity. Therefore, over time the activity becomes less physically challenging and requires less work to perform; consequently, the body burns fewer calories and conserves energy compared to initial exercise sessions.

Obesity is generally associated with sedentary behavior. Obese individuals sit for about 2.5 more hours per day than lean, sedentary individuals (Levine, Vander Weg, Hill, & Klesges, 2006). This may suggest that obese individuals are less inclined to be active than non-obese individuals or that daily activities are more tiresome for these people and require periods of recovery. Non-exercise activity thermogenesis (NEAT) consists of all energy expenditure that is not achieved by eating, sleeping, or planned exercise (Levine, et al., 2006). Obese populations did not show a decrease in NEAT in the days following a moderate intensity exercise session or a vigorous intensity exercise session (Alahmadi, 2011). This suggests that obese individuals do not compensate for an exercise session by decreasing non-exercise caloric expenditure. However, in a population of older adults (aged 56-78), vigorous intensity activity did not increase daily energy expenditure due to the fact that these individuals compensated for the activity by being more sedentary the rest of the day (Goran & Poehlman, 1992). Despite these findings, no study to date has examined the presence of compensatory sedentary behavior (as opposed to only change in NEAT) in a middle-aged obese population. Additionally, further study is needed to examine the presence or absence of compensatory sedentary behavior outside the scope of prescribed exercise sessions in order to get a more naturalistic view of compensatory responses.

Benefits of Physical Activity

Engaging in regular physical activity has been associated with prevention of premature death as well as many chronic diseases (e.g., obesity, diabetes, cardiovascular disease, cancer, depression, osteoporosis, and hypertension) (Warburton, Nicol, & Bredin, 2006). Prevention may occur through the mechanisms of increased insulin resistance caused by physical activity as well as the change in distribution of adipose tissue, which are both important for decreasing cardiovascular risk (Despres, et al., 1990; Henriksen, 2002). Increasing physical fitness has been associated with lower rates of mortality as well as mortality from cardiovascular disease (Blair, et al., 1995; Paffenbarger, et al., 1993). Additionally, an increase in physical activity level is also associated with preventing weight gain over time (Di Pietro, Dziura, & Blair, 2004). However, the importance of physical activity intensity is widely debated.

The Debate about Moderate versus High Intensity Activity

Vigorous intensity activity (e.g., jogging or running, swimming laps, and bicycling 10 miles per hour or faster) has been linked with lower rates of mortality as compared to moderate or low intensity activity (such as casual walking or bowling) (Lee & Paffenbarger, 2000). Studies have also shown decreases in cholesterol following prescription of vigorous intensity activity (Duncan, Gordon, & Scott, 1991; Kraus, 2002). In addition, when energy expenditure of activity was held constant, increasing vigorous intensity activity decreased the amount of visceral abdominal fat (which is associated with increasing insulin resistance), while increasing moderate intensity activity showed no significant change in these fat levels (Coker, Williams, Kortebein, Sullivan, & Evans, 2009). Men who regularly perform vigorous intensity activity carry lower amounts of body fat than those who do not engage in vigorous intensity activity despite decreased caloric intake in the non-vigorous intensity population. This suggests that the increased post-exercise energy expenditure caused by vigorous intensity activity may aid this population in burning more calories at rest. Therefore, these men maintain a lower level of body fat (Yoshioka, et al., 2001). With regard to weight regain after the end of a weight loss intervention, consistently partaking in vigorous intensity activity has been associated with lower amounts of weight regain compared with moderate or low intensity activity in a population of premenopausal women (Mekary, Feskanich, Hu, Willett, & Field, 2009).

Despite the myriad health and body composition benefits of adding vigorous intensity activity, individuals may not engage in exercise that is subjectively very challenging (Oman & King, 1998). Therefore, moderate intensity activity also continues to be a recommended form of exercise by the American College of Sports Medicine (Garber, et al., 2011). Moderate intensity activity has some important health benefits as a review of 10 studies showed that adhering to the recommended amount of moderate intensity physical activity has been associated with lower risk of developing type 2 diabetes, independent of performing vigorous intensity activity (Jeon, Lokken, Hu, & van Dam, 2007).

Some studies have found that duration of physical activity is more important for health benefits than intensity. Houmard et al. (2004) found that greater total duration of exercise (~170 min/week vs. ~115 min/wk) was more important for improving insulin sensitivity than intensity of physical activity (moderate vs. vigorous). Individuals that exercised an average of 170 min/week at either a low-volume/moderate intensity or a high-volume/high intensity had similar improvements in insulin sensitivity despite differences in estimated caloric expenditure (1,200 kcal vs. 2,000 kcal, respectively). However, insulin sensitivity was less enhanced in the individuals in the low-volume/high intensity group. Despite having the same estimated caloric expenditure as the high-volume/moderate intensity group (1,200 kcal), the low-volume/high intensity group only exercised for an average of 115 minutes per week (Houmard, et al., 2004). In a population of sedentary, overweight women, there were no differences in weight loss based upon duration (moderate vs. high) or intensity activity (moderate vs. vigorous); however, individuals that were exercising greater than 200 minutes per week 6 months and 12 months after the baseline assessment showed a greater decrease in weight than individuals exercising less than 150 minutes per week at these time points (Jakicic, Marcus, Gallagher, Napolitano, & Lang, 2003).

In conclusion, there are clear weight loss benefits of vigorous intensity activity over low intensity activity, as the caloric deficit generated by the higher intensity is much greater than low intensity activity (Imbeault, 1997). However, there continues to be debate about whether vigorous intensity activity is more beneficial for weight loss than moderate intensity activity in adults (Shaw Kelly, Gennat Hanni, O'Rourke, & Del Mar, 2006). Despite the fact that increasing vigorous intensity activity has been associated with weight loss, lower rates of mortality, decreased cholesterol, and decreased amounts of visceral abdominal fat, if people do not engage in this type of exercise they will not achieve the associated health benefits (Coker, et al., 2009; Duncan, et al., 1991; Lee & Paffenbarger, 2000). Moderate intensity activity also has important health benefits (i.e., weight loss and decreasing the risk of type 2 diabetes) and, being subjectively easier than vigorous intensity activity, may have greater levels of adoption and adherence (Jeon, et al., 2007; Oman & King, 1998). However, some researchers argue that duration, independent of exercise intensity and caloric expenditure are more beneficial for weight loss (Houmard, et al., 2004; Jakicic, et al., 2003).

Specific Aims and Hypotheses

This study has two specific aims. The first aim sought to determine whether a change in average daily minutes of physical activity was associated with weight change after six months of a weight loss intervention. We hypothesized that increases in daily minutes of moderate intensity activity would be associated with a decrease in body weight. We further hypothesized that an increase in minutes of vigorous intensity activity would have an added benefit with regard to weight loss over the addition of moderate intensity activity.

The second aim of the study was to determine if performing vigorous intensity activity resulted in compensatory sedentary behavior. Among individuals who completed vigorous intensity activity at either the baseline assessment or the six month assessment, we hypothesized that individuals in this study would compensate for vigorous intensity activity by being more sedentary the rest of the day.

CHAPTER 2
MATERIALS AND METHODS
Research Methods and Procedures

Rural LITE

The current study was a secondary analysis of data from the *Rural Lifestyle Intervention Treatment Effectiveness* Trial (Rural LITE) (Perri, 2008). The Rural LITE trial was a randomized control trial funded by the National Heart, Lung, and Blood Institute. Rural LITE was aimed at determining the cost-effectiveness of four models of lifestyle weight management treatment. The study was conducted in ten rural counties in northern Florida and was comprised of two phases. At the beginning of the initial treatment phase, participants were randomly assigned to one of four conditions: Simplified, Low, Moderate, or High. Conditions differed in the number of sessions offered throughout the two year intervention. The Simplified and Low conditions would meet for 16 sessions, the Moderate condition would meet for 32 sessions, and the High condition would meet for 48 sessions; however, an equal number of sessions would be conducted in the first phase and second phase of treatment (i.e., for the Low condition, 8 sessions take place in the first six months and 8 in the following 18 months). All treatment conditions received educational information, but only the Low, Moderate, and High conditions also included weekly goal setting and problem solving as well as required daily completion of dietary intake and physical activity records.

The initial treatment phase consisted of up to six months of weekly in-person group sessions that focused on aiding individuals in weight loss through the use of educational information about nutrition, physical activity, and cognitive strategies. For the Low, Moderate, and High conditions, dietary goals focused on decreasing caloric intake through setting goals of 1200-1500 kcal intake for women and 1500-1800 kcal intake for men while also aiming to improve the quality of their diet. Such improvements focused on decreasing saturated fat intake and increasing fruit, vegetable, and whole grain intake. Physical activity goals, for the three treatment conditions, focused on increasing daily steps, as measured by a pedometer, by at least 3,000 steps from the beginning of treatment to the end of treatment. Individuals were also encouraged to set planned physical activity goals amounting to an average of 30 minutes per day at least six days per week.

The second phase of the Rural LITE study consisted of an 18-month maintenance and extended care phase. Individuals no longer met on a weekly basis, but took part in telephone sessions as well as five weekly in-person sessions called campaigns. Individuals in the Simplified and Low conditions had one telephone session and one campaign. Individuals in the Moderate condition had four telephone sessions and two campaigns while individuals in the High conditions had six telephone sessions and three campaigns. Individuals in the Low, Moderate, and High conditions were encouraged to continue keeping daily records of their dietary intake and physical activity throughout the extended care phase.

Participants

The current study included 181 healthy, obese men and women between the ages of 24 and 74 (M = 53.8, SD = 10.5 years) with a mean weight of 99.9 kg (SD = 14.6) and a mean BMI of 35.6 kg/m^2 (SD = 3.3). The majority of the participants were female (75%). Within the Rural LITE study, the majority of participants identified as Caucasian/White (82%). 16% of individuals identified as African-American/Black, 5% as Hispanic/Latino, 1% as American Indian or Alaskan Native, 1% as Asian and less than 1% as Native Hawaiian or Pacific Islander. Baseline characteristics can be found in Table 2-1.

Inclusion criteria for the study were that individuals had to be between 18 and 75 years old, have a BMI between 30 and 45 kg/m^2, and weigh less than 181.8 kg (400 lbs). In addition, they had to be able to participate in the study for the following two years and be relatively healthy other than their weight.

Exclusion criteria for the study were that individuals could not have lost more than 10 pounds in the preceding 6 months. Individuals were excluded if they had a condition that would influence the outcome of treatment, their ability to participate in group sessions, or prevent eating and physical activity behavior changes. Exclusionary conditions included medical conditions such as a reported history of cancer within the last five years (an exception was made for non-melanoma skin cancer), serious infectious disease (such as tuberculosis or human immunodeficiency virus), myocardial infarction, congestive heart failure, stroke, uncontrolled angina within the last six months, chronic hepatitis, cirrhosis, chronic malabsorption syndrome, chronic pancreatitis, irritable bowel syndrome, a history of bariatric surgery, a history of a solid organ transplant, musculoskeletal conditions that could limit physical activity (such as rheumatoid arthritis), chronic lung diseases that limit physical activity, glucose > 125 mg/dL, fasting serum triglycerides > 400 mg/dL, blood pressure at rest > 140/90 mg/Hg, or another physical condition that would limit their 5-year life expectancy or significantly interfere with their ability to participate in a lifestyle intervention involving eating and physical activity changes.

In addition, women were excluded if they were pregnant, planning to become pregnant within two years of the beginning of the study, or breast feeding. Individuals were excluded if they were currently using antipsychotic medication, chemotherapeutic medications, monoamine oxidase inhibitors, systemic corticosteroids, human immunodeficiency virus or tuberculosis antibiotics, or weight-loss medications. Individuals who reported a significant psychiatric disorder or excessive use of alcohol were also excluded as well as those who were unwilling to provide informed consent, were currently participating in another research study, were unable to read English at a fifth grade level, or were unwilling to be randomly assigned to a treatment condition.

Of the 2,879 men and women who responded to the study recruitment announcements, 1,366 were excluded at the telephone screening phase, 441 did not attend an in-person screening assessment, and 318 were excluded after completing the in-person screening assessment. Among the 2,125 men and women who were not eligible for participation, 96 were excluded due to elevated blood pressure, 93 had abnormal lab values, 632 had contraindications based on medical history, 25 has some other abnormal result during screening, 510 had a BMI that was out of range, and the remaining individuals were excluded due to an age that was out of range, lack of rural residence, or other non-medical issues.

Procedures

Individuals in the current study were recruited through the use of random mailings as well as in-person recruitment conducted at churches, community centers, businesses, and community events. Individuals that were interested in the study completed a screening measure over the telephone and, if they met eligibility criteria, were scheduled for an in-person screening assessment. At that in-person assessment, individuals were provided with an informed consent that they were asked to read and sign if they wanted to continue the process to take part in the study. After providing the informed consent, the individuals were asked to complete a number of questionnaires that asked not only about demographic information, but also about their diet, physical activity, medical history, medication use, quality of life, problem-solving strengths and weaknesses, family and self weight history, and current health state. In addition, a registered nurse collected a blood sample as well as height, weight, waist size, resting heart rate, and blood pressure. Individuals also completed a 400-meter walk test to assess their current level of mobility and physical fitness.

Individuals who were eligible based upon findings from the in-person assessment visit were asked to return for a follow-up visit within 2 weeks prior to their first group session. At the second screening assessment, weight was measured to determine if individuals had gained more than 4.5 kg (10 lbs) since the first screening visit and women were given a pregnancy test to ensure that they were not with child, as caloric restriction can be harmful to babies in utero.

After all eligibility requirements were met, participants were assigned group meeting times. Their ranking of availability was taken into account for this process. All participants who attended the first group meeting were asked to complete and return food records as part of a final eligibility requirement. Only after they completed and returned these records the next week could they be randomized into a treatment condition. Starting at the first group session of the weight management lifestyle intervention program, participants were asked to wear an electronic armband that used sensors and triaxial accelerometry to measure caloric expenditure. They were instructed to wear it as close to 24 hours per day as possible, excluding times when it could get wet other than sweating (i.e., bathing or swimming). After six months in the weight management lifestyle intervention program, individuals were asked to wear this device for another week.

Measures

Body Weight. Body weight was measured using a digital scale and weight was recorded to the nearest tenth of a kilogram. Weight was measured at months 0 and 6 by a registered nurse who was unaware of the treatment condition as well as by an interventionist at the beginning of each group session during both the initial treatment phase and the secondary maintenance phase. Men and women were weighed in light clothing, without shoes, and with nothing in their pockets. Weight change during the initial treatment phase was determined by calculating the difference in body weight between months 0 and 6.

Minutes of Physical Activity by Intensity. In order to provide an objective measure of physical activity minutes and intensity, a Sensewear® WMS Armband was used. This electronic device was worn on the tricep of the non-dominant arm for one week at month 0 and again six months into the study. Data from the armband was included in the analysis only when the device was worn for at least 21 hours per day. The armband had multiple sensors that measure motion, body heat, skin temperature and conductivity as well as triaxial accelerometry. Validation studies have proven the reliability and validity of this device for exercise activities as well as sedentary behavior (Andre, et al., 2006; Fruin & Rankin, 2004; G. A. King, Torres, Potter, Brooks, & Coleman, 2004). After participants returned the device to the interventionists, the data from the device was uploaded to a computer and matched to previously inputted personal body parameters about that participant including age, height, weight, gender, smoking status, and handedness. An algorithm provided by Sensewear® analyzed the information from the armband with the previously inputted body parameters to determine intensity of physical activity on a minute-by-minute basis, number of steps per day, and total daily energy expenditure.

Intensity of physical activity was measured in metabolic equivalents (METs). One MET is the energy expenditure for an individual “at rest” which is calculated using the aforementioned body parameters. Two people at rest will burn a different amount of calories, but they both burn one MET. Therefore, METs are a multiplier of calories; if an individual is performing at three METs, he/she will burn three times the amount of calories as when he/she is at rest. Physical activity intensity zones were divided in the following way: Sedentary is <3 METs, Moderate is 3-6 METs, and Vigorous Intensity is 6+ METs (Sallis & Owen, 1999). METs were used to determine the amount of minutes of physical activity spent in each of the three zones. This information was used in the analysis of the relationship between physical activity intensity and weight change as well as the assessment of compensatory sedentary behavior after performing vigorous intensity activity.

Sedentary Caloric Expenditure. In order to assess for compensatory sedentary behavior, an objective measure was needed to not only distinguish individuals that performed vigorous intensity activity from those that did not, but also to determine the amount of sedentary calories burned in a day. The Sensewear® algorithm provided information about total daily energy expenditure based upon personal body parameters of the participants and data from the sensors on the armbands. In addition, the amount of calories burned during physical activity (classified as ≥ 3 METs) was also provided. Total daily energy expenditure was calculated by adding sedentary calories burned in a day to physical activity calories burned. Therefore, sedentary caloric expenditure was calculated by obtaining the difference between total daily energy expenditure and calories burned during physical activity.

Attendance. Due to the fact that individuals were randomized into different treatment conditions, percent attendance to in-person group sessions was used as an indicator of adherence to treatment.

Macronutrient composition. The National Cancer Institute's Diet History Questionnaire (DHQ) is a food frequency questionnaire that assesses intake of specific foods over the past 12 months (Subar, et al., 2000; Subar, et al., 2001; Thompson, et al., 2002). This questionnaire showed the highest correlation with 24-hour recalls when compared with two other food frequency questionnaires (i.e., the Block Food Frequency Questionnaire and the Willett Food Frequency Questionnaire) (Subar, et al., 2001). The Diet*Calc Analysis Program provided by the National Cancer Institute was utilized to analyze the DHQ. This software generated micronutrient and macronutrient estimates as well as daily caloric intake. The measurements provided by Diet*Calc were used to determine the macronutrient (i.e., carbohydrate, protein and fat) intake at month 0 and month 6. Macronutrient intake was utilized, as opposed to daily caloric intake, due to the fact that it has been shown to be a more valid measure of self-reported eating behavior with delayed recall (Subar, et al., 2003; Subar, et al., 2001).

Statistical Analyses

IBM®'s SPSS® statistical software version 18.0 was used for all analyses (Armonk, New York). To evaluate the first aim, association between physical activity intensity and weight change, a hierarchical multiple regression was conducted with percent weight change as the dependent variable. For the first level of the regression, age and a dichotomized gender variable were entered as the independent variables. For the second level of the regression, percent attendance, change in protein intake, change in carbohydrate intake, and change in fat intake were included as independent variables as well as change in daily minutes of moderate intensity physical activity. Due to the fact that change in daily minutes of moderate intensity physical activity and change in daily minutes of vigorous intensity physical activity were positively correlated (Pearson correlation: $r = .331$), daily minutes of vigorous intensity activity was added as a third level in the regression model. This hierarchical analysis ensured that the analysis would provide the additional benefit of vigorous intensity activity over that which was already explained by the addition of moderate intensity activity. All change variables were determined by calculating the difference between the measure at month 0 and month 6.

To evaluate the second aim, we focused the analysis only on those individuals who had completed vigorous intensity activity at either month 0 (N = 24) or month 6 (N = 25). Separate analyses were conducted for month 0 and month 6 to ensure that individuals with vigorous intensity activity at both time points were not overrepresented in a single analysis. Due to the small sample size, a bootstrapping analysis was conducted with 1000 samples. In order to assess for the presence of compensatory sedentary behavior at each time point, we utilized a paired samples t-test. Sedentary behavior was defined as less than 3 METs. Therefore, the analysis was conducted by comparing the average sedentary calories an individual burned on a day when they completed vigorous intensity activity to the average sedentary calories an individual burned on a day when they did not complete vigorous intensity activity. If the amount of sedentary calories burned was significantly greater on days when individuals engaged in vigorous intensity activity, this would demonstrate compensation for the vigorous intensity activity.

Table 2-1. Participant baseline characteristics

Characteristics	
Age in years, *M* (*SD*)	53.8 (10.5)
BMI in kg/m^2, *M* (*SD*)	35.6 (3.3)
Gender, n (%)	
Male	44 (24.3)
Female	137 (75.7)
Ethnicity, n (%)	
Hispanic/Latino	5 (2.8)
Other	176 (97.2)
Race, n (%)	
White	155 (85.6)
Black	17 (9.4)
Multiracial	7 (3.9)
Asian	2 (1.1)
Highest Level of Education, n (%)	
Some high school	9 (5.0)
Earned a GED	3 (1.7)
High school diploma	19 (10.5)
Vocational or trade school diploma	29 (16.0)
Some college - No college degree	48 (26.5)
Associates degree/2-yr college	26 (14.4)
Bachelor's degree/4-yr college	20 (11.0)
Some college or professional school	11 (6.0)
Master's degree	15 (8.3)
Doctoral/professional degree	1 (0.6)
Marital Status, n (%)	
Never Married	6 (3.3)
Divorced or separated	24 (13.3)
Widowed	9 (5.0)
Presently Married	134 (74.0)
Living in marriage like relationship	8 (4.4)

CHAPTER 3
RESULTS
Weight and Dietary Changes

At month 0, individuals had an average weight of 99.9 kg (*SD* = 14.6) and at month 6, individuals had an average weight of 90.0 kg (*SD* = 15.1). Over the course of six months in the weight management lifestyle intervention program individuals lost an average of 10.0% of their body weight (*SD* = 6.39). This suggests that the average woman who started the program at 96.1 kg (210 lbs) lost about 9.6 kg (21 lbs) over the six month period.

The Diet History Questionnaire demonstrated that the average daily caloric intake at month 0 was 1997.5 kcal (*SD* = 1015.9) with daily caloric intake decreasing by month 6 to an average of 1447.8 kcal (*SD* = 701.0). As seen in Table 3-1, further analysis showed that the composition of dietary intake caused this decrease in intake. Individuals decreased their protein intake from an average 80.8 g/day to 65.0 g/day, carbohydrate intake from 230.1 g/day to 181.2 g/day, and fat intake from 85.8 g/day to 52.6 g/day.

Association between Nutrition and Physical Activity Changes and Weight Change

The variables entered in the first level of the hierarchical multiple regression (i.e., age and gender) were not significantly associated with percent weight change from month 0 to month 6. These variables remained non-significant in the second level when percent attendance, change in protein intake, change in carbohydrate intake, and change in fat intake were included as independent variables as well as change in daily minutes of moderate intensity physical activity. Vigorous intensity activity was added in the third level of the regression in order to determine if there was an additional benefit over moderate intensity activity. Percent attendance was not associated with percent weight change, $p = .278$. When all variables were included in the regression they explained a significant proportion of variance in percent weight change, R^2 = .258, $F(8, 172) = 7.469$, $p < .001$, Table 3-2.

Dietary changes were associated with weight change over time. Specifically, an increase in percent of energy consumed from carbohydrate was associated with a decrease in body weight over time, β = -.747, $t(172)$= -3.17, p = .002. Similarly, an increase in percent of energy consumed from protein calories was also associated with a decrease in body weight over time, β = -.370, $t(172)$= -3.01, p = .003. The change in percent of calories consumed of fat intake was not associated with weight change over time, p = .083.

At month 0, participants in the study engaged in 49.2 minutes of moderate intensity activity daily (*SD* = 38.0) with a range from 2.2 minutes to 215.8 minutes. At month 6, participants had increased their minutes of moderate intensity activity to 59.1 minutes daily (*SD* = 41.5) with a range from 6.0 minutes to 224.8 minutes. Over the six month period, participants increased moderate intensity activity by 9.9 minutes per day (approximately one hour per week). Within the regression model, an increase in average daily minutes of moderate intensity physical activity was associated with a decrease in body weight over six months in the weight management lifestyle intervention, β = -.197, $t(172)$ = -2.72, p = .007.

Participants engaged in an average of 0.9 minutes of vigorous intensity activity daily (*SD* = 3.2) at month 0 with a range from 0 minutes to 30.8 minutes. At month 6, participants had increased their minutes of vigorous intensity activity to 1.1 minutes daily (*SD* = 4.1) with a range from 0 minutes to 41.0 minutes. Over the six month period, participants increased daily vigorous intensity activity by 0.2 minutes per day (approximately one minute per week). The increase in average daily minutes of vigorous intensity activity was associated with a decrease in body weight above that achieved through increasing moderate intensity activity, $\beta = -.210$, $t(172) = -2.905$, $p = .004$. Given that not all participants engaged in vigorous intensity activity at month 0 or month 6, an analysis was conducted solely using those who participated in this intensity of activity at one of the time points. These participants increased their vigorous intensity activity by approximately 3.5 minutes per week.

A post-hoc analysis was completed to determine demographic characteristics of participants engaging in vigorous intensity activity. Participants who completed vigorous intensity activity were not significantly different in age than those who did not complete vigorous intensity activity, $p = .264$. There was also no significant difference in gender among those who completed vigorous intensity activity and those that did not, X^2 (1, N = 181) = 3.427, $p = .064$. Black/African American individuals were more likely to complete vigorous intensity activity as compared to White/Caucasian individuals, X^2 (1, N = 172) = 8.315, $p = .004$. There were no significant differences in completion of vigorous intensity activity among other races and ethnicities. A full list of demographics can be found in Table 3-3.

Compensatory Sedentary Behavior[1]

In order to assess for the presence of compensatory sedentary behavior, a comparison of the average sedentary calories an individual burned on a day when they completed vigorous intensity activity to the average sedentary calories that individual burned on a day when they did not complete vigorous intensity activity was conducted. At month 0, individuals burned an average of 2390.0 kcal (*SD* = 351.1) doing sedentary activity on days when they completed vigorous intensity activity. On days when they did not complete vigorous intensity activity, individuals burned an average of 2405.0 kcal (*SD* = 548.0) doing sedentary activity. The

[1] Month 6 armband data for 20 participants was erased prior to being uploaded to the computer.

bootstrapping analysis of 1000 samples determined that there was no significant difference between the amount of sedentary calories burned on vigorous activity days as compared to no vigorous activity days, $p = .853$, 95% CI [-231.4, 167.0]. At month 6, individuals burned an average of 2237.1 kcal ($SD = 411.1$) doing sedentary activity on days when they completed vigorous intensity activity. On days when they did not complete vigorous intensity activity, individuals burned an average of 2314.0 kcal ($SD = 398.7$) doing sedentary activity. The 1000 sample bootstrapping analysis from month 6 data determined that there was no significant difference between the amount of sedentary calories burned on vigorous activity days as compared to no vigorous activity days, $p = .075$, 95% CI [-.16, 154.6].

A post-hoc analysis was conducted to determine whether a difference in compensatory sedentary behavior was seen based on age. Individuals under the age of 56 did not show a trend toward compensatory sedentary behavior at either month 0 or month 6 ($p = .965$, $p = .200$, respectively). Adults aged 56 and older also did not compensate for sedentary behavior at month 0 or month 6 ($p = .523$, $p = .099$, respectively).

Table 3-1. Change in predictors of weight loss over time

	Month 0		Month 6	
	Intake in grams	Intake as percent of total daily calories	Intake in grams	Intake as percent of total daily calories
Protein intake, *M* (*SD*)	80.8 (45.4)	16.3 (3.5)	65.0 (33.6)	18.0 (3.5)
Carbohydrate intake, *M* (*SD*)	230.1 (113.8)	47.1 (9.0)	181.2 (83.3)	51.0 (9.2)
Fat intake, *M* (*SD*)	85.8 (52.8)	37.6 (6.8)	52.6 (32.0)	32.0 (7.1)
Daily caloric intake in kilocalories, *M* (*SD*)	1997.5 (1015.9)		1448.0 (701.0)	
Body weight in kilograms, *M* (*SD*)	99.9 (14.6)[a]		90.0 (15.1)[b]	
Average moderate intensity activity per day in minutes, *M* (*SD*)	49.2 (38.0)		59.1 (41.5)	
Average vigorous intensity activity per day in minutes, *M* (*SD*)	0.86 (3.2)		1.15 (4.1)	

a. Female = 96.1kg; Male = 111.4kg

b. Female = 86.5kg; Male = 100.3kg

Table 3-2. Hierarchical multiple regression analysis[a]

Variable	Model 1 B	Model 1 β	Model 2 B	Model 2 β	Model 3 B	Model 3 β
Constant	-9.565**		-5.879		-7.187*	
Age	-.010	-.016	.016	.027	.015	.026
Gender	.089	.006	.658	.045	1.004	.068
Percent attendance			-4.174	-.104	-2.974	-.074
Change percent of daily calories of protein			-.691**	-.423	-.606**	-.370
Change percent of daily calories of fat			-.317*	-.403	-.272	-.346
Change percent of daily calories of carbs			-.508**	-.806	-.471**	-.747
Change daily moderate intensity minutes			-.046***	-.259	-.035**	-.197
Change daily vigorous intensity minutes					-.333**	-.210
R^2		.000		.221		.258
F		.031		7.028***		7.469***
ΔR^2				.221		.036
ΔF				9.824***		8.439**

a. Dependent variable: percent weight change
Note: *p <.05. **p < .01. ***p <.001.

Table 3-3. Demographic characteristics of individuals by exercise intensity

	Completed vigorous intensity activity	Did not complete vigorous intensity activity
Age in years, *M* (*SD*)	52.0 (9.3)	54.1 (10.8)
Gender, n (%)		
Male	15 (34.8)	29 (21.0)
Female	28 (65.2)	109 (79.0)
Ethnicity, n (%)		
Hispanic/Latino	1 (2.3)	4 (2.9)
Other	42 (97.7)	134 (97.1)
Race, n (%)		
White	33 (76.8)**	122 (88.4)
Black	9 (20.9)**	8 (5.8)
Multiracial	1 (2.3)	6 (4.3)
Asian	-	2 (1.4)

Note: **p < .01.

CHAPTER 4
DISCUSSION

The purpose of the current study was to determine how changes in physical activity were related to weight change and sedentary behaviors. Specifically, we sought to examine the association between change in amount of two intensities of physical activity (i.e., moderate and vigorous) over time and weight loss. The study also examined for the presence of compensatory behavior, in the form of increased sedentary behavior, after engaging in vigorous intensity activity.

While people were asked to add 30 minutes of moderate intensity exercise per day over the six month intervention period, and many of them reported that they had made these increases, data from the armband showed that they added one-third of that amount. The discrepancy could result from the fact that individuals may not be monitoring the intensity of their exercise and walking at a pace below the moderate level. However, participants who increased average daily minutes of moderate intensity activity over the six month period showed a decrease in body weight. Guidelines from the American College of Sports Medicine and Centers for Disease Control and Prevention suggest that individuals engage in 2.5 hours (150 minutes) of moderate intensity physical activity per week (Garber, et al., 2011). Current findings suggest that the addition of one hour of moderate intensity physical activity per week was adequate for establishing a calorie deficit and subsequent weight loss.

Given the ongoing debate about the benefits of adding vigorous intensity activity as compared to moderate intensity activity, it was important to understand the nuances of these changes within the context of our study. Therefore, the variance associated with the increase in minutes of vigorous activity over that which was already explained by the increase in moderate intensity activity was utilized for analysis. The analysis showed that increasing minutes of vigorous intensity activity by an average of one minute per week had additional weight loss benefits over the addition of moderate intensity activity. This suggests that high intensity activity may have an important role in the management of weight.

There was no significant difference in the gender or age of individuals who completed vigorous intensity activity compared to those who did not. However, a greater proportion of Black/African-American individuals completed vigorous intensity activity compared to White/Caucasian individuals. There were no significant differences in completion of vigorous intensity activity when comparing Black or White individuals to Multi-racial individuals. Given the small sample size of Black/African-American individuals in the study (N = 17), a larger sample size is required to determine if these results may generalize to the broader population.

Previous study has suggested that older individuals (aged 56-78) compensate for vigorous intensity activity by increasing sedentary behavior (Goran & Poehlman, 1992). However, it was important to examine the effect of this behavior in a broader population. In addition, the previous study examined the presence of sedentary behavior following prescribed vigorous activity sessions whereas the current study observed vigorous activity performed at the discretion of the participant. The current study found no evidence that this population compensated for vigorous intensity activity by increasing sedentary behavior. In replicating the analysis by Goran and Poehlman and assessing individuals aged 56 and older, there was no trend towards compensatory sedentary behavior being significant. Given that the overall population was small (N = 14), it is possible that a larger sample would yield similar results as the Goran and Poehlman study.

Greater minutes of sedentary behavior throughout the day have been associated with higher rates of mortality regardless of whether individuals engage in planned moderate or vigorous intensity exercise sessions throughout the day (Patel, et al., 2010). This suggests that even if participants engaged in vigorous intensity activity, they may still be at risk for negative health consequences if they compensated by being more sedentary. The finding from the current study suggests that the addition of vigorous intensity activity does not lead to sedentary behavior or preclude obese individuals from engaging in physical activity of moderate intensity.

These findings have implications for treatment and future research. Given the benefits of both moderate and vigorous intensity activity, there may be an opportunity to add varying intensities of physical activity in stages of a weight management interventions. For example, when participants master adding 30 minutes of moderate intensity activity (i.e., walking) per day, they can progress to adding vigorous intensity activity, such as power walking or walking on an incline. Previous studies have shown that one of the main concerns with regard to vigorous intensity activity in obese populations has to do with potential injury, especially from joint impacts (Cooper, et al., 1998; Davis, et al., 1989; Hu, et al., 2009; Marks, 2007). Walking is a low impact form of exercise that can be modified to be moderate or vigorous in intensity and does not require the use of special equipment needed by other low impact activities (i.e., swimming or bicycling).

Intensity of physical activity is a measure that is defined in a continuous manner. However, in the field of physical activity intensity research, METs are divided into intensities categorically. Therefore, it would also be important to examine physical activity intensity more closely within intensity zones. There may be variation in the intensity of sedentary activity on days when a person engages in moderate or vigorous intensity activity. For example, the average METs of sedentary activity may be 2.5 METs on days without vigorous intensity activity and 1.5 METs on days with vigorous intensity activity. Given that compensatory sedentary behavior was determined using total sedentary calories, nuances of intensity within this zone as well as the moderate zone were not examined. Participants may not have compensated by engaging in more sedentary behavior generally, but there may be changes in the intensity of sedentary behavior. Similarly, future research should seek to determine if there is variation in the intensity of moderate intensity activity on days with an individual engages in vigorous intensity activity.

Not all participants in Rural LITE engaged in vigorous intensity activity so the sample size available for analyses of compensatory sedentary behavior was small (total N = 49). Given the relatively small proportion of individuals that engaged in vigorous intensity activity in this population, it would be important to determine if there are particular characteristics that these higher achievers shared. It is possible that individuals with more motivation were better adherers and challenged themselves to achieve greater levels of fitness and physical activity. Daily food record completion rates may serve as an indicator of greater motivation and should be analyzed in future research.

Future studies should also aim to assess a larger sample to determine if compensatory sedentary behaviors are present. Despite the fact that an assessment of older participants, similar to those in the Goran and Poehlman study, did not find evidence of compensation the results may be affected by a small sample size. A larger sample would allow participants' compensatory behavior, or lack thereof, to be analyzed based on age. This research may help determine if there are different responses to vigorous intensity activity across the lifespan.

Limitations and Strengths

Given the aforementioned results and implications of the study, it is also important to review its limitations. The current study was conducted with a population from rural communities. Therefore, there may be differences in access to resources that aid in engaging in physical activities (i.e., fitness centers and safe, well-lit walking areas) as compared to urban or suburban populations. It is unclear if this access might influence the addition of moderate or vigorous intensity physical activity minutes in populations from other geographic locations or in compensatory sedentary behaviors following vigorous intensity activity.

A second limitation of the study is that the Sensewear® Armand was worn by the participants for one week at two time points (months 0 and 6). While the data gives information about that particular week, it is unclear if the week that the participant wore the armband is representative of their usual physical activity level. For example, due to the fact that participants were aware that the interventionists would see their physical activity levels they may have modified their exercise for the week.

A third limitation of the study is that in the Rural LITE intervention, we did not manipulate the addition of moderate or high intensity activity as a variable. Participants were encouraged to increase daily walking as the primary form of physical activity, but it was not a requirement for remaining in the weight management intervention. Walking is a form of low impact physical activity that would cause less stress on the joints of obese individuals than the addition of a high impact activity such as jogging. In addition, people in rural communities who may not have access to fitness centers due to cost or proximity can engage in walking without specialized equipment. However, walking is a form of moderate intensity activity. Therefore, if participants only focused on adding walking, as opposed to adapting other exercise behaviors over time, they may not have engaged in vigorous intensity activity over the course of the intervention. This may partially explain why only 27% of participants included in the first aim engaged in vigorous intensity activity and were able to be used in the analysis of compensatory sedentary behavior.

The current study has several important strengths. The focus of many weight loss studies is in examining individuals in an urban or suburban population. This study was conducted solely with individuals from rural communities and, therefore, examined a relatively under-served and under-studied portion of the population in the United States of America.

Another important strength of this study is that it examined the addition of moderate and vigorous intensity activity outside the boundaries of a prescribed physical activity regimen. Previous studies required participants to engage in physical activity in a laboratory setting (Goran & Poehlman, 1992; Jakicic, et al., 2003); however, the current study examined a more natural progression of physical activity. Ultimately, participants added physical activity at their ability and discretion. These results may offer an example of how obese populations increase physical activity in a typical weight management intervention and may aid future interventions in constructing exercise guidelines that prompt individuals to exercise at the intensity the interventionists desire.

Summary

In summary, obesity is a major health concern in the United States and many weight management interventions are aimed at combating this problem. However, there continues to be debate about whether obese individuals can achieve the amounts of moderate intensity activity necessary for weight loss, whether vigorous intensity activity is more beneficial than moderate intensity activity, and if vigorous intensity activity results in compensatory sedentary behavior. Obese individuals lost an average of 10.0% of their body weight after six months in a weight management intervention. Increases in moderate and vigorous intensity activity were associated with weight loss over the six month period. There was no evidence of compensatory sedentary behavior in individuals who engaged in vigorous intensity activity.

Overall, the findings from the current study suggest that adding both moderate and vigorous intensity activity may be beneficial for aiding obese populations in their weight loss efforts. The interventionists did not manipulate the addition of moderate or vigorous intensity activity; therefore, not all participants engaged in vigorous intensity activity during the course of the study. Future treatment of obese populations may benefit from prescribing stages of physical activity that become more challenging over time. This may provide a safe way to add vigorous intensity activity throughout the course of an intervention. Ultimately, the addition of physical activity of moderate and vigorous intensities are important factors in weight loss and should be considered as components of future weight management interventions without concerns that vigorous intensity activity will cause compensatory sedentary behavior.

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BIOGRAPHICAL SKETCH

Danielle Marie Lespinasse was born in Freehold, New Jersey. She graduated from Freehold High School in 2003 where she excelled in athletics. Danielle attended Yale University. She graduated in 2007 with a Bachelor of Arts in psychology and received the Cogswell Award for conspicuous service to the college. Following graduation, Danielle worked in the Wealth Management division of Merrill Lynch, Pierce, Fenner, and Smith from 2007-2010 focusing on the management of managed products and their transition into Bank of America during the merger of the companies. While working in the financial services industry, Danielle found that her passion was in fitness and nutrition. More specifically, she developed an interest in these areas as they related to obesity as well as the cognitive mechanisms associated with this disease. It was for this reason that she entered the Clinical and Health Psychology doctoral program at the University of Florida in Gainesville, Florida in the fall of 2010. Danielle completed her Master of Science in 2012 and is currently pursuing her research interests in the areas of obesity and physical activity.