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Compensatory behaviors during a 12-week vigorous interval intervention in post-bariatric men and women

Kristen Byrne

Compensatory Behaviors During a 12-week Vigorous Interval Intervention in Post-Bariatric Men and Women

Kristen Byrne

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FACULTY COMMITTEE:

Committee Chair: Jeremy D. Akers, PhD, RDN

Committee Members/Readers:

Elizabeth S. Edwards, PhD, FACSM

David L. Wenos, PhD

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Abstract

Strong links have been recognized between sedentary time, higher BMI, and waist circumference among post-operative bariatric surgery patients. The time-efficient aspects of the High Intensity Interval Training show a significant influence in creating a habitual strategic exercise for fighting obesity and controlling compensatory components. Ten post-operative bariatric participants (9 females, 1 male) with BMI of 33.65 ± 2.90 kg/m^2, undergoing a 12-week Vigorous Intensity Interval Training (VIIT) program, were assessed for the compensatory mechanisms of sedentary behavior and caloric intake. Participants were evaluated through 4-day food intake records and ActivPal accelerometers, assessed using Nutrition Data System for Research and PAL Software, respectively. Post-operative bariatric participants completing a 12-week VIIT did not significantly increase sedentary behavior (111.9 ± 6.9 vs. 115.5 ± 13.1, $p > .05$) or caloric intake (1546.8 ± 608.1 vs. 1405.3 ± 525.4, $p > .05$), and were able to maintain their baseline weight (195.1 ± 54.5 vs. 195.8 ± 55, $p > .05$). VIIT may be an effective exercise modality to decrease unwanted compensatory behaviors and assist with long-term weight loss maintenance.

Introduction

Globally, rates of severe obesity (BMI ≥ 40 kg/m^2) are increasing faster than any other disease, resulting in over 2.5 million obesity-related deaths, annually.[1,2] Obesity is multifaceted and results from imbalances in energy consumed and energy expended, creating a positive energy balance leading to excess body weight. A decrease of as little as 2-3% of weight loss has been reported by the National Heart, Lung, and Blood Institute (NHLBI) as beneficial in improving chronic disease risks in overweight/ obese individuals.[3–8] A weight loss of this degree can create marked progress in risk factors for diabetes, heart disease, [5,9] some cancers and all-cause mortality, as well as a cessation of medications.[10–13] For severely obese individuals who have exhausted all other weight loss options, those at high risk for morbidity and mortality from weight-related comorbidities are eligible for bariatric surgery. There are numerous surgical procedures for weight loss, but for the purpose of this review, only the two most common will be discussed. These two include Roux-en-Y gastric bypass (RYGB) and Laparoscopic Sleeve Gastrectomy (LSG).

Bariatric surgery has been identified as one of the most effective interventions to help patients obtain extreme and continuous weight loss, as well as enhanced metabolic and overall health.[1,2,14–16] The average weight loss following the first two years of all bariatric surgeries is 50-75% of excess weight.[17,18,19] Despite the health benefits of bariatric surgery, several reported behaviors hinder weight loss postoperatively (e.g. inactivity and overconsumption).[20] To lose more fat mass (FM) and preserve a large percentage of FFM (fat-free mass), behavioral adjustments need to be incorporated; one needs to follow a low-calorie diet and perform moderate physical activity (PA). Research indicates weight regain is common 2-10 years after surgery.[1,21–23]

An additional correlation to weight gain includes leisure-time activities related to sitting (but are not considered restful behaviors) such as getting <6 or >8 hours of sleep and increased screen time. [24] A sedentary lifestyle with little participation in MVPA (moderate-to-vigorous physical activity) may play a part in post-surgery weight regain, as well as low PA levels, eating behavior disorders and low QoL (quality of life).[25] The total volume of MVPA is linked to many health benefits, while the bouts of a prescribed duration are not crucial.[26] Guidelines show that almost all individuals can benefit from moving more and sitting less.[26] Those individuals that execute the least amount of PA benefit most by even moderate increases in MVPA. Therefore, these benefits are more related to the overall volume as opposed to bout length.

Increased PA can have both short- and long-term benefits including lower risk of mortality, lower risk of CVD (cardiovascular disease) and related risk factors (hypertension and type 2 diabetes), stroke, lower risk of many cancers, energy balance, as well as weight control.[26] Despite PA recommendations for weight loss control and avoidance of weight regain recommending moderate PA,[27,28] smaller durations of vigorous activity may be adequate to obtain sufficient weight control.[29] The time-efficient characteristics of a high intensity exercise regimen possess an advantage in developing a habitual strategic exercise for combating obesity and has been found to be more helpful than continuous endurance training. According to Herman et. al, more than 60 minutes of exercise per session in moderate-intensity circuit training (MICT) was almost double that of the interval exercises in high-intensity interval training (HIIT).[30] Even though there was a body fat elimination proportionate between the MICT and HIIT, the time-efficient

aspects of the HIIT showed a significant influence in creating a habitual strategic exercise for fighting obesity.

Aerobic activity and or weight training[31] along with increased PA[32] have been successful in preventing high levels of adiposity and losing and maintaining body weight. This is where HIIT is capable of producing benefits with less than the recommended amount from guidelines, of 30 minutes a day of PA. Therefore, interval training is concluded to be more helpful than continuous endurance training in establishing a time-efficient lifestyle meditation for controlling obesity.[33,34] Individuals that are overweight and obese often create barriers to executing PA [35] due to weight misperceptions.[36] The majority of vigorous interval training interventions performed thus far have included only general population subjects. This may be due to time, physical capabilities, and/or other barriers that restrict the bariatric population to participate in the duration of a study. Exercise protocols and small bouts of exercise are found to decrease postprandial appetite hormones (PYY, ghrelin, glucagon-like polypeptide) causing a reduction in hunger and food intake. Weight-loss related to energy deficits can be attributed to compensatory responses.[37] Self-reported inadequate dietary adherence after a bariatric procedure is linked with a decrease in weight loss results.

Therefore, the purpose of this study was to determine if compensatory behaviors arise from post-bariatric men and women throughout a 12-week vigorous-intensity interval training intervention. We hypothesized that the post-bariatric participants will increase their sedentary behavior and their daily caloric intake during this 12-week vigorous interval exercise intervention. While participating in this shorter duration

training session, dietary intake and sedentary time outside of the lab were collected via food intake records and an accelerometer.

Overweight and Obesity

In 2016, 39% of adults were overweight and 13% were obese according to the World Health Organization (WHO). This escalation in obesity is credited to a nutritional transition to processed foods and high-calorie diets, economic advancement, motorized transportation, industrialization, shifts from rural to urban living, and an increase in a sedentary lifestyle.[24] Globally, rates of severe obesity (BMI $\geq$ 40 kg/m^2) are increasing faster than any other disease, resulting in over 2.5 million obesity-related deaths, annually.[1,2]

Overweight and obesity are defined as excess body weight for one's height.[24] Obesity is multifaceted and results from imbalances in energy consumed and energy expended, creating a positive energy balance leading to excess body weight.[24,38] The complexities of obesity are extensive and increase the likelihood of reduced physical activity (PA) and increased sedentary behaviors (SB) adding to a revolving cycle of obesity.[38]

Body mass index (BMI; body weight in kilograms divided by height in meters squared) is most commonly used to classify weight-for-height.[24] Increased BMI is related to joint pain and decreased physiological function[39,40] such as damaged cardiorespiratory function,[41] inflammation of the immune system, psychological disorders, and decreases in flexibility, movement,[40,42,43] and muscle strength.[44, 45]Additionally, obesity is linked to cardiovascular disease (CVD), type 2 diabetes mellitus (T2D), hypertension (HTN), hyperlipidemia, certain cancers, stroke, sleep apnea, liver and gallbladder disease,

osteoarthritis, as well as premature mortality.[20, 24, 30, 38, 46, 47] Obesity increases the chances of morbidity and mortality due to its complexity involving genetics, environmental, socioeconomic, and behavioral origins.[24]

A decrease of as little as 2-3% of weight loss has been reported by the National Heart, Lung, and Blood Institute (NHLBI) as beneficial in improving chronic disease risks in overweight/ obese individuals.[3–8] While this amount is not guaranteed to cause an obese individual to restore to a non-obese state, a weight loss of this degree can create marked progress in risk factors for diabetes, heart disease,[5,9] some cancers and all-cause mortality, as well as a cessation of medications.[10–13] Overall, weight loss has been linked to notable changes in physical health, mental well-being, and total quality of life (QoL).[48,49]

Weight Loss Strategies

Among presently approved remedies for obesity and linked metabolic comorbidities are lifestyle modifications (diet, physical activity, behavioral changes), and surgical interventions.[50] One of today's most prominent and clinical weight-loss approaches is a caloric restriction.[24] Evidence has shown that following a caloric restricted diet, seemingly regardless of the macronutrient distribution, affects weight loss. Sacks et al. randomly assigned 811 overweight adults to one of four diets; the intended percentages of energy coming from fat, protein, and carbohydrates in the diets were: 20, 15, and 65%; 20, 25, and 55%; 40, 15, and 45%; and 40, 25, and 35%, respectively.[51] All four diets contained homogeneous foods and followed guidelines for cardiovascular health. Due to weight loss being the highest 6-12 months after starting a diet, with steady weight regain afterward, this study observed weight change over two years. Subjects

were selected to be in one of the four diet groups and were educated on several diets that accentuated different macronutrient contents as well as received support through individual and group sessions for two years. Overall, despite the macronutrient contents of these four diets, all subjects were successful in losing weight regained.[51] There have been several dietary approaches and studies regarding weight loss since the 2013 obesity guidelines have been published.[52] Regardless of the dietary method, be it a food group, time pattern, or nutrient-based approach there is no proof that one is more effective than another. Overall, findings have shown that if energy reduction is achieved, there will be health benefits, whether it be in body composition or a decrease in the risk of developing chronic diseases. It is highly recommended that clinicians promote dietary plans and physical activity regimens that fit an individual's preference.[52]

Exercise is often used as a weight-loss approach due to its capability to raise energy expenditure and, thus, to create a negative energy balance. Even when supervised, weight loss from exercise is prone to fluctuation.[26] Inadequate PA in the US is attributed to approximately 10% of premature deaths and a predicted $117 billion in annual health care costs.[26] As of 2016, only 26% of men and 19% of women met PA recommendations. Despite individuals knowing that routine PA is advantageous to their health/well-being and that they should incorporate more PA into their daily routine, current data continues to exhibit that levels of PA are inadequate.[26]

The prolonged duration of exercise sessions, being the basis of moderate-intensity continuous training (MICT) regimens, reduces abdominal visceral fat in obese individuals. Since training-induced changes in abdominal visceral fat are more prevalent in men,[53] future studies need to be gender-specific for the minimum intensity and training

volume to reduce fat.[54] Furthermore, exercise intensity noticeably increases lipolytic hormones including growth hormone and catecholamines.[55,56]

A study focusing on weight loss strategies reviewed the consequences of a diet and exercise intervention versus a diet-only intervention on both short-term and long-term weight loss.[57] Compared to a diet only program, a combined diet and exercise program produces an increased long-term weight loss, especially in interventions that lasted a year or longer. However, as stated previously, many weight loss plans promote diet more than PA.[10]

Behavioral or lifestyle interventions are thought to be the foundation of obesity treatment and are designed to generate long-term weight losses.[58] Lifestyle interventions assist individuals in losing 5-10% weight loss within 6 months, averaging about one to two pounds per week. Behavioral programs encourage progressive increases in PA by utilizing moderate-intensity exercises, such as brisk walking.[58] A 30-minute duration of brisk walking is believed to use 150 - 300 kcal based on body weight; this would serve as an average of 20% of energy intake in a normal post-weight loss surgery patient.[59] It is recommended that at the start of PA, patients partake in 50 minutes of activity per week, with a steady increase to 150 minutes per week. Short bouts of 10 minutes can be performed and compiled over the course of the day to achieve these recommendations. [58]

Kiernan et al. (2001) found that the addition of PA to a diet only intervention accentuates weight loss in overweight men and women.[60,61] Regardless of the way weight is lost, the amount of lost weight has a great influence on psychological health. In this study of 264 overweight individuals with a BMI of 28-34 kg/m^2 and BMI of 24-30 kg/m^2 for men and women, respectively, both sexes lost a significant amount of weight,

although men were found to have more psychological benefits from the addition of PA.[60,61] This may have been due to decreased hunger; a change in appetite hormones, after exercising, which in turn may have increased their weight loss, therefore, leading to enhanced psychological benefits.[61]

Goodpaster et at. (2010) conducted a randomized trial on 130 severely obese individuals.[62] Subjects were divided into two groups; one group had PA and diet for all 12 months, while the other group had delayed PA; PA was added to their diet only weight loss intervention 6 months after initiating the program. At 6 months, both groups lost weight, although the initial activity group lost significantly more than the delayed activity group. Weight loss at the end of the 12-month study was evident in the two groups. Therefore it was concluded that PA should be implemented in addition to dietary restriction to slightly, but clearly, induce greater weight loss and improve cardiometabolic risk factors.[62] To avoid weight gain, or to assist in weight loss, typically 150-250 minutes per week of moderate-intensity activity is recommended to be combined with dietary restriction, in comparison to reduced intake alone.[24,59]

In addition to expending energy through planned exercise, individuals can make adjustments in posture and movement that are linked with habits of everyday life, which is generally associated with light-intensity physical activity (LIPA).[63] While LIPA has currently been found not to benefit one's health, it is capable of beginning the expenditure process.

For severely obese individuals who have exhausted all other weight loss options, those at high risk for morbidity and mortality from weight-related comorbidities are eligible for bariatric surgery. In 1991, the National Institute of Health (NIH) set

qualifications of bariatric surgery at a BMI of ≥ 40 kg/m^2 without co-morbidities and for those with a BMI of ≥35 kg/m^2 with obesity-related complications, such as T2D, HTN, and or sleep apnea.[20,46,49,60] In 2020, it is predicted that there will be over a million people that have undergone bariatric surgery.[64]

Surgical techniques are typically organized into restrictive procedures, where the stomach's accommodation is smaller; malabsorptive procedures, in which malabsorption is the key to weight loss; or a mix of restrictive and malabsorption. Any surgery modifying the GI tract can alter gut physiology;[1] thus the traditional view that bariatric surgery works mainly through restriction/malabsorption of nutrients has been outdated; it is now acknowledged that its mechanisms of action are mainly physiologic and not mechanic.

The elemental structure of the potential positive effects of bariatric surgery is complicated and encompass several changes in, but not limited to, GI anatomy, diet and behavior, and GI hormonal responses [such as leptin, ghrelin, and peptide YY (PYY)].[65] There are numerous surgical procedures for weight loss, but for the purpose of this review, only the two most commonly performed will be discussed. These two include Roux-en-Y gastric bypass (RYGB) and Laparoscopic Sleeve Gastrectomy (LSG). Following gastric bypass surgery, 95% of the stomach is restricted, with the upper stomach being completely closed off.[7] Bariatric surgery has been identified as one of the most effective interventions to help patients obtain extreme and continuous weight loss, as well as enhanced metabolic and overall health.[1,2,14–16]

There are better chances of increased weight loss with bariatric surgery than with lifestyle interventions [45,66] and/or a drug regimen.[20] The permanent procedure of

RYGB,[21] commonly known as the gold standard of bariatric procedures, promotes improvements in diabetes remission and cardiovascular risk and accelerates weight loss.[14,49,67,68] Additionally, RYGB is linked with better glycemic control than any other form of medical regimen, in that it enhances glycemic control, with a 40 to 80% rate of recovery from hyperglycemia in T2D patients.[14]

Weight loss peaks in the first two years following bariatric surgery. The average weight loss following the first two years of all bariatric surgeries is 50-75% of excess weight.[17,18] This allows for the chance to regulate long-term weight and metabolic results, with near steady weight.[19] In a study of 140 subjects with diabetes or weakened glucose tolerance became euglycemic following RYGB.[7] Additionally, insulin release, insulin resistance and usage of glucose were considerably improved, as well as fasting insulin and glycosylated hemoglobin decreasing to normal levels. Lower glucose levels occur in response to nutrients being exposed to leptin sensing jejunal receptors, causing leptin to be released into the jejunum.

Obese individuals have shown a resistance to leptin often due to high circulating levels of the hormone. After RYGB, leptin levels can drop before any actual weight loss, which in turn leads to a mirroring effect of lost weight. While overseeing the amount of fat in the body, the brain checks for shifts in leptin levels in an attempt to reduce weight.[38] To maintain homeostasis, leptin levels decrease when a person is fasting or losing weight, creating a modified energy intake, and neuroendocrine functioning. At this time, hyperphagia develops and other hormones are triggered, including ghrelin, insulin, and glucagon.[38]

PYY hormone is capable of crossing the blood-brain barrier to act on the arcuate nucleus, resulting in additional weight loss and a restricted appetite directly after consuming a meal.[14] Though this response is lost in obese patients, however, RYGB has been found to re-establish PYY response to nutrient intake; an effect that is more evident compared to procedures that solely restrict gastric volume without resection or bypass.[14]

Despite the health benefits of bariatric surgery, several reported behaviors hinder weight loss postoperatively (i.e. inactivity and overconsumption).[20] Thibault and Pichard (2016) found that fat-free mass (FFM) is one of the first aspects of the body to go due to quick weight loss 1 year after surgery.[69] To lose more fat mass (FM) and preserve a large percentage of FFM, behavioral adjustments need to be incorporated; one needs to follow a low-calorie diet and perform moderate physical activity (PA). A decreased %FM before bariatric surgery is linked to greater odds of achievement of significant weight loss (SWL) after surgery.

Evaluation of the results of bariatric surgeries should be of both complete weight loss and improvement of obesity-related medical disorders.[7] The loss of at least 50% of excess weight after bariatric surgery has been used as the minimum basis for success. This basis for successful weight loss can be illustrated as the percentage of excess weight loss (%EWL), where %EWL = weight loss/excess weight x100, and excess weight = total weight pre-bariatric surgery - ideal weight.[21]

In a study of 100 post-bariatric men and women, it was found that six months to a year post-surgery the number of patients with BMI >40 kg/m^2 had decreased from 69% to 14% excess body weight.[45] Many factors may contribute to a lower total energy expenditure post-RYGB, but the main effects are reasonably due to a decrease in FFM

and a decrease in caloric intake.[70] Additionally, it is important to have proper protein intake post-operatively due to the loss of FFM that may occur due to rapid weight loss.[59] This reinforces the need for a patient's nutritional status to be closely monitored to guarantee proper dietary intake.

For an increase in aerobic capacity and cardiorespiratory function [reflected by maximal oxygen consumption (VO2 peak)] after bariatric surgery, engaging in regular PA is fundamental, due to individuals not only losing fat but also losing lean mass (LM), notably in the first three postoperative months.[71–73] It is established that LM loss occurs in conjunction with weight and fat loss after bariatric surgery,[73] which may help lower VO2 peak in this period, as peripheral oxygen extraction relies on active skeletal muscle mass. A retrospective study of 27,320 post-bariatric subjects was conducted to identify the underlying causes of obtaining a BMI of < 30 kg/m^2 after surgery.[74] Although patients with a high BMI of ≥ 45 kg/m^2 before undergoing surgery benefit the most, they continue to be morbidly obese even after exceptional weight loss and still possess the same weight-related comorbidities. Patients with a BMI of < 40 kg/m^2 before surgery were more likely to attain a BMI of <30 kg/m^2 and decrease weight-related comorbidities post-surgery.[74] However, less than 9% of bariatric patients with a BMI of >50 kg/m^2 reach this goal. Furthermore, bariatric surgeries are not a "miracle cure." Although there are several effective strategies for weight loss, maintaining lost weight has remained difficult.[21]

Weight Loss Maintenance

Reasons for weight regain are uncertain, but it is believed that behavioral, medical[22] and anatomical factors[22,75] influence weight regain.[76] Psychological and

nutritional habits are included in these behavioral factors. Research indicates weight regain is common 2-10 years after surgery with up to 15% of an individual's initial body weight being regained; half of the individuals return to their pre-surgery weight five years following surgery.[1,21–23] Therefore, this is a reason that exercise interventions post-surgically are vital for this population.

Engagement in PA during the first 3-6 months after surgery was found to be inadequate.[77] Despite RYGB being an efficient procedure, research states that 15-35% of patients will not reach gratifying weight loss or will regain the weight previously lost, leading to a reduction in control of comorbidities linked to obesity.[22,78] Potential weight regains or lack of weight loss can be due to an inadequate practice of behavioral strategies, poor dietary intake, and sedentary behavior (SB).[21]

An underlying cause of poor weight loss post-bariatric surgery is disproportionate energy intake. A crucial factor in the variation of weight loss between procedures, as well as overall long-term weight loss results, is postoperative eating behaviors, especially following a RYGB procedure. Dietary control is needed for several reasons to help postoperative patients, such as increasing their adherence to healthy habits and intaking supplementation and preserve previously lost weight.[79]

SB is defined as any waking behavior that has an energy expenditure of 1.5 METs or less and engagement of no more than 20 minutes a day for more than 3 days a week.[26,49] A concern that SB is a public health problem is due to the negative connections with health outcomes and that it has become a frequent behavior in the US.

In a study conducted by Crisp et al. (2017) the amount of time that 17 of 34 post-RYGB surgery women participated in moderate-to-vigorous physical activity (MVPA) changed notably from preoperatively to 6 months postoperatively, but no variation was seen at 12 months.[75] This study reviewed PA variables post-surgery with depletion of FFM and an increase of FM loss. Between 6 and 12 months after RYGB surgery there was a significant decrease found in fat loss and body mass, but no difference found for FFM. The major findings of this study were: 1) at 6 months postoperative the percentage of time in MVPA increased, 2) both before and after surgery most of the subjects were classified as being physically inactive, 3) in the postoperative period there were no observed changes in SB and 4) FFM and SB were inversely linked at 6 and 12 months after surgery. This study found female bariatric patients spent most of their day (~77%) in sedentary activities before and after surgery.[75]

Strong links have been recognized between sedentary time, higher BMI, and waist circumference among obese individuals that have had bariatric surgery.[70] Physical inactivity is a phrase used to express failure to manage the suggested minimal MVPA for progressing and preserving physical fitness and health.[77,80] A decrease in sedentary time can lead to reduced cardiovascular risk, regardless of time spent doing MVPA.[63] A sedentary lifestyle with little participation in MVPA may play a part in post-surgery weight regain, as well as low PA levels, eating behavior disorders and low QoL.[25] In another study, an accelerometer was used to objectively measure PA; it was found that in correlation with other studies, bariatric patients spend most of their awakening hours in sedentary activities, which did not increase postoperatively.[81–83]

Several of the fourteen adult subjects in a qualitative study reported that some obesity-related physical barriers were still present 12 months after surgery.[84] However, these same individuals stated that they had an increased ability to participate in activities due to a reduction in most of their obesity-related barriers, such as body pain and self-presentational concerns. Non-obesity related barriers to PA were also present at 12 months post-surgery. Both lack of motivation and time are most frequently reported as pre-surgery barriers to PA.[84,85]

Zabatiero et al. (2016) found that subjects regularly explained scarce PA after surgery due to having already achieved substantial weight loss and that this was a time of adaptation and recovery from the surgical procedure.[84,86,87] Once post-surgery adjustments are accepted, usually 6 months after surgery, subjects reported the motivation to perform PA increases due to feeling confident and an increased ability to participate in activities of daily living.[84] While initial beliefs regarding consistent participation in PA tend to be centered around weight loss/health benefits, these beliefs change following weight loss surgery as they see a decrease in weight loss without a change in PA behaviors and therefore perceive PA as unnecessary. As stated previously, the maintenance of weight loss is difficult, however, there are several diet and PA strategies that can be executed to maintain successful weight loss.

Strategies to Weight Loss Maintenance

Few individuals succeed in long-term weight loss maintenance (WTLM). Research has revealed that approximately 20% of overweight individuals are capable of maintaining 10% of the weight they previously lost for at least one year.[88] The duration of successful maintenance of weight loss is the best predictor of the risk of weight regain.

Those that can keep excess weight off for two or more years, are considered successful and have a decreased risk of weight regain by approximately 50%.[10,21,88] Research has shown that a major necessity for achieving favorable weight loss is the practice of lifestyle changes.[21] To maintain weight lost it is essential to balance energy consumed with energy expended. While bodyweight maintenance is and should be regarded as a complex interaction between genetic, environmental, and socioeconomic factors, but generally an individual's behavior following these circumstances continues to be associated with preventing weight regain.[24]

A review written by Wing and Hill (2001) suggests that WTLM gets effortless over time, i.e. over time your strategies become everyday behaviors.[10] It is important to note that successful weight maintenance may entail some weight regain. Additionally, both the quality and quantity of foods absorbed play a vital role in WTLM. A reduction in calories from fat, [89,90] reduced portion sizes,[91] and lower caloric intake,[92] enable individuals to be successful at WTLM. In a behavioral weight loss follow-up study by Wing et al. (2001), it was found that those who faithfully monitored their caloric intake managed a higher weight loss than those who infrequently self-monitored.[10]

Early detection of weight regain due to frequent monitoring permits initiation of action to halt the trend and stop any relapse.[21] Odom et al. found one of the most preventative strategies against weight regain postoperatively was self-monitoring.[48] This belief is evident in weight management in non-bariatric groups, which demonstrates that food records, regular weigh-ins, and PA diaries are crucial tools for preventing weight regain. The importance of regular long-term follow-up and anthropometric measurements is emphasized to avoid weight regain, which often occurs in a steady and continuous

matter.[21] Additional self-monitoring tools that are ideal to obtain and maintain weight loss after surgery are cognitive strategies, practical goal setting, visualization, and support systems.[48]

Over a 5-year follow-up period, the National Weight Control Registry (NWCR) assessed long-term maintenance weight loss in 784 men and women who had lost an average of 30 kg and maintained a mandatory minimum weight loss of 13.6 kg.[50] Individuals reported their demographics, weight characteristics, and weight maintenance methods and strategies. Overall, dietary adjustments, fulfilling daily PA and self-monitoring weight were the most prevalent strategies linked to long-term weight control. The NWCR concluded that by adhering to a mixture of strategies, subjects were more prone to lose and maintain weight as compared to individuals who only utilized one basic set of strategies.[50]

Furthermore, bariatric patients must endure lifelong regular evaluations and interventions as needed, to obtain and maintain optimal weight loss[48] and health benefits. It is suggested that the patient is informed of how their procedure works to enhance long-term weight loss.[21] Additionally, the patient should be provided with: preoperative and postoperative educational discussions, customized nutritional supplements, and pureed foods. Information regarding self-control of liquid kilojoules, grazing habits and eating out of the home, and participating in an average of 60 minutes of PA per day.[48] Patients should plan to have persistent annual medical, psychological, and dietary evaluations.

To guarantee the long-term success of any bariatric intervention and the patient's continued devotion to a regular diet and exercise regimen to avoid relapse, a

multidisciplinary team approach is necessary.[50] To increase their weight loss, patients will need guidance to aid them in adapting to their new eating habits.[21,48] Also, it is imperative that the patient becomes aware of their body's signals and can assess when to stop eating; this can be accomplished by eating slowly, in a relaxed manner and avoiding distractions.

The total volume of MVPA is linked to many health benefits, while the bouts of a prescribed duration are not crucial.[26] Adequate PA is described as at least 75-150 minutes a week of vigorous-intensity aerobic PA or 150-300 minutes a week of moderate-intensity, or a proportionate consolidation of moderate- and vigorous-intensity aerobic activity. It is shown that both aerobic and muscle-strengthening PA are beneficial. Therefore, muscle-strengthening activities should be executed two or more days a week.[26]

Guidelines show that almost all individuals can benefit from moving more and sitting less.[26] Those individuals that execute the least amount of PA benefit most by even moderate increases in MVPA. With that said, evidence reveals that bouts of any length of MVPA promote health benefits similar to that of accumulated volumes of PA. Cardiometabolic disease (CMD) risk factors that are improved by performing high-intensity interval training (HIIT) are similar in magnitude to those arising from MICT aerobic exercise. However, it has been found that weight status impacts the outcome of HIIT to decrease CMD risks.

Increased PA can have both short- and long-term benefits including lower risk of mortality, lower risk of CVD and related risk factors (HTM and T2D), stroke, lower risk of many cancers, energy balance, as well as weight control.[26] Improvements in cognition,

bone health, insulin sensitivity and quality of sleep have been identified following an increase in PA. In addition, PA diminishes the risk of dementia, anxiety and depression, and blood pressure. Even one bout of activity can be advantageous and show immediate health benefits.

Despite PA recommendations for weight loss control and avoidance of weight regain asserting moderate PA,[27,28] smaller durations of vigorous activity may be adequate to obtain sufficient weight control.[29] Virtually all public health agencies recommend PA as an integral part of weight management.[8,93,94] The American College of Sports Medicine recommendations of PA state that adults should partake in aerobic activity of at least 150 minutes per week at moderate intensity, 10,000 steps a day[95] or 75 minutes of vigorous-intensity PA, in bouts of 10 minutes.[59,78,93,96,97] The 2013 American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society suggest 200-300 minutes a week to maintain any lost weight or to minimize weight regain in the long term.[24,58,59,95]

It should be stated that more than 60 minutes of exercise per session in MICT was almost double that of the interval exercises in HIIT.[30] Even though there was a body fat elimination proportionate between the MICT and HIIT, the time-efficient aspects of the HIIT showed a significant influence in creating a habitual strategic exercise for fighting obesity. The specific fat loss resulting from MICT is dependent upon the training volume, as shown in the dose-response relationship between aerobic exercise-induced energy expenditure and visceral fat reduction in metabolically healthy obese individuals.[33] Aerobic activity and or weight training[31] along with increased PA[32] have been successful in preventing high levels of adiposity and losing and maintaining body

weight. Therefore, interval training is concluded to be more helpful than continuous endurance training in establishing a time-efficient lifestyle meditation for controlling obesity.[33,34]

The purpose of a study conducted by Svetkey et al. (2008) at 4 clinical centers was to compare two WTLM interventions with a self-directed control group.[98] Two phases of clinical trials were formed for this study. Phase 1 included all subjects, where they executed a weight loss intervention for 6 months. Phase 2, a randomized 30-month trial, compared two-weight maintenance strategies - interactive technology and personal contact vs. self-directed control condition. Weight loss of at least 8 pounds during phase one permitted subjects to continue into phase two. Several factors were applied; diet was tracked by the Block Food Frequency Questionnaire and PA measured by an accelerometer worn for at least four days at a time. Goals of phase one were for subjects to partake in 180 minutes per week of MVPA; accept the Dietary Approaches to Stop Hypertension (DASH) dietary pattern, which has been proven to decrease CVD risk factors; reduce caloric consumption and lose on average one to two pounds per week.[98]

Those subjects that adhered to these goals were included in phase two and were randomly assigned to one of three groups.[98] One group received a minimal intervention, another group was encouraged to frequently log on to an interactive based website, and the third group had personal-contact interventions once a month. Results showed that all three groups gained weight following the 12-month intervention. However, the self-directed minimal intervention group gained significantly more than the personal-contact group; 5.5 kg and 4.0 kg, respectively. From this study, it was determined that people flourish from different intensities of intervention and for different durations.[98]

From an observational longitudinal study conducted on 25-64-year-olds, with an average postoperative BMI of 32.7 ∓ 6.9 kg/m^2, it is stated that there is not enough information available regarding weight self-regulation and the nature of motivation in overweight and obese patients.[15] Subject's quality of motivation was determined by the use of a version of the Treatment Self-Regulation Questionnaire (TSRQ), to evaluate influences to continue regulating weight. Independent self-regulation was higher than externally controlled regulation, regarding impulses to keep executing weight loss after LSG. Also, external motivations were linked with decreased weight loss.[15] Educating patients on how to deal with external cues may decrease weight regain and/or relapse.[99]

An observational study on changes in PA and SB by King et.al (2015) included 473 bariatric subjects.[78] The analysis showed that a surgical procedure was not a predictor of changes in PA and/or sedentary parameters. However, subjects were more active at all post-surgery measurements compared to pre-surgery. Sedentary time declined by 28 minutes a day from pre-surgery to a one-year post. Findings from the study suggest that this group of adults made small but significant changes from pre- to one-year postoperative in ambulatory PA and MVPA with a decrease in SB, and maintained these changes throughout the third year of follow up. Although PA increased and SB decreased, current MVPA recommendations were not met. There is a need to integrate pre- and post-surgery PA counseling in clinical care settings despite the slight changes that were made because most patients continue to have low levels of activity through the first 3 years postoperative.[78]

In-person PA counseling has been shown by the latest randomized controlled trial studies to be effective for increasing daily MVPA in candidates for bariatric surgery,[100]

and these changes made were maintained at 6 months after surgery.[101] Weight regain and return of comorbidities are not infrequent.[102,103] Of 56 bariatric female subjects in a prospective cross-sectional study, 73% reported a weight regain of 5-30% of maximal weight initially lost.[22] Patients that have some weight regain (at least 15%) have lower QoL scores compared to weight-stable patients and a similar score to preoperative patients, although they have a lower BMI. Combining bariatric surgery with behavioral interventions, such as those commonly used for weight maintenance patients, may help to prevent weight regain.[22,48]

In a study of 77 post-LSG patients [3, 6, and 12 months post-surgery], it was found that one year after surgery bariatric patients have medium to high adherence to primary lifestyle suggestions; this adherence is not connected to an increase in weight loss.[96] Adherence to suggested supplementation is correlated with improved micronutrient quality one year after surgery. The subjects in this post-LSG study increased the time spent in exercise from pre-surgery and most proclaimed exercising routinely for the first year postoperative; however, they did not reach the suggested goal of 150 minutes or more a week.[96] Due to the study's duration only being 12-months, it was difficult to determine the link between PA and long-term weight loss.

For weight loss after bariatric surgeries, PA and increased casual exercise establish an important long-term weight control strategy.[21] To lower the possibility of weight regain, postoperative patients should raise their PA levels to preserve muscle mass and increase weight loss. Weight regain following bariatric surgery can be foreseen if low levels of PA are executed. A minimum of 60 minutes of MVPA daily, either consecutively or split up, has been shown to be adequate for maintaining weight loss.[21]

RYGB subjects one to three-months postoperative in a cross-sectional intervention were asked to wear an accelerometer on their upper arm for no less than 7 days and no more than 14 days in a row.[104] On average all PA dimensions were increased by subjects during surgery-induced weight loss. This study found that an escalation in PA is linked with a reduction in BMI and fat mass. Predominantly during the first three months after surgery,[105] some LM is lost along with FM.[104] Between three and 9 months after surgery there is a continued loss of LM. At levels of at least 150 minutes per week of MVPA[106] , it has been shown that this duration and intensity of PA can lessen the amount of LM lost during this time of caloric restriction.[104]

Barriers to Success

Individuals that are overweight and obese often create barriers to executing PA[35] due to weight misperceptions.[36] Individuals that partake in a form of PA but are not meeting suggestions of activity duration are more likely to miscalculate their actual weight or misperceive themselves as being a normal weight. Active individuals are more aware of the associated health benefits from PA. However, those that partake in sedentary activity are less likely to misperceive their weight, due to the awareness of time spent being sedentary.[107]

According to Murillo et al. (2016) participating in some PA, compared to none, correlates with weight misperception in adults.[107] Subjects were asked to describe any activity they participated in, including work and transportation activities, and the duration that was spent in these activities. They also were to report information on minutes of sedentary time per week. Those that partook in medium to high rates of SB, compared to low, had a decreased chance of misperceiving their weight. Amidst overweight and obese

people, those that properly perceive themselves as overweight are more likely to participate in PA compared to those that report themselves as "underweight" or "about the right weight". Subjects that misperceived their weight participated in more leisure-time physical activity (LTPA), work- and transportation-related PA compared to individuals that were correctly aware of their weight. Type of activity, in addition to the sex of an individual, has an impact on the link of PA and weight misperception.[107]

The majority of vigorous interval training interventions performed thus far have only included general population subjects. This may be due to time, physical capabilities, and/or other barriers that restrict the bariatric population to participate in the duration of a study.

In a study conducted by Ferriby et al. (2017), pre- and post-surgery male and female bariatric subject's awareness of their weight status classification (WSC) is essential to oversee, due to those that correctly perceive their WSC before surgery is more likely to possess motivation for health behavior changes.[108] Weight misperceptions are the differences in perceived weight status and actual weight.[36] Healthcare staff typically do not share WSC and therefore, patients must conclude their own WSC, which is often impacted by social norms. Following bariatric surgery, the first year is when the majority of their weight is lost, which potentially could make it a challenge for individuals to correctly perceive their WSC. Females perceive their WSC to be higher than actual WSC while males perceive their WSC as lower than actual WSC. Individual's perceived WSC impacts their motivation to pursue weight mediation, as well as bariatric surgery. Motivation to progress with behavioral and weight goals are solely based on not overestimating one's WSC.[108]

Excessive skin is often an unforeseen obstacle to weight loss following bariatric surgery.[21] It has been found that after a significant weight loss an individual may have an abundance of excess skin and soft tissue redundancy, leading to the prevention of continued weight loss. This abundance of excess skin may cause musculoskeletal strain from the increase in tissue weight and/or inflammation, resulting in a reduction in both planned and incidental exercise. Due to excessive skin commonly being visible, it is necessary to acknowledge the social impacts this may have on an individual's self-esteem, social acceptance, and body image, all of which can result in a diminished urge to participate in physical activity in the public eye.[21]

A study performed to find predictors of QoL, included 155 participants post RYGB and LSG.[16] Due to patients' expectations being high or even impractical, the continued presence of comorbidities and mediocre weight loss after having a procedure may lead to poor physical and mental QoL. This decline in QoL may later result in depressive reactions and rejections of any recommendations.[16]

Adhering to certain post-operative recommendations, such as follow-up appointments with the surgeon and dietitian, PA and dietary suggestions have all been proven to predict weight loss outcomes.[109] Although factors underlining self-reported dietary adherence have not been identified, it has been continuously determined as having the largest impact on postoperative weight loss outcomes.[109,110] Self-reported PA has been shown to raise after bariatric surgery.[111] This phenomenon may be due to an increased health-related quality of life (HrQoL) and enhanced functional capacity that leads patients to feel more active and over-report their PA after surgery. Several

maladaptive eating behaviors lead to an immense amount of post-RYGB patients' low self-reported dietary consistency and an increase in postoperative weight regain.[22]

Grazing is characterized as the consumption of smaller amounts of food repeatedly over a lengthened time period.[21] It is a prevalent concern that affects many bariatric patients pre- and postoperatively, possibly compromising long-term weight loss success if not regulated. People who graze throughout the day defeat the purpose of surgical procedures to limit the amount of food eaten in one sitting, leading to the consumption of too many kilojoules. Social and/or psychological circumstances often provoke these grazing behaviors.[21]

A randomized controlled 22-week diet and exercise-based trial of 89 overweight and obese individuals aged 18-50 years old were conducted to find if different types of PA influenced compensatory actions.[112] King et al. (2007) noted compensation of increased SB, decreased non-exercise PA and/or expanding caloric intake after high energy expenditure was common among several individuals. Accelerometers were used to measure energy expenditure once a month and instructions were given with a PA diary for tracking duration and intensity of any activity being performed. Based on findings from the accelerometer, LIPA increased after 3 months and again at the end of the 22-week intervention by 8 and 11%, respectively. Bodyweight, fat and abdominal fat percentages before the intervention were positively correlated with amounts of SB and negatively correlated with LIPA, MVPA, and overall PA level. SB and LM percentages were found to be negatively correlated as well, while LM was positively correlated with all types of PA. At the end of the intervention, correlations were the same between all variables, except LIPA presented a low but significant correlation with body weight.

Findings did not show compensatory changes in SB and LIPA in return of participating in the interventions. While there was no group effect from the intervention, there was an effect of time. LIPA increased and percent of SB decreased after the study.[112]

Exercise protocols and small bouts of exercise are found to change postprandial appetite hormones (PYY, ghrelin, glucagon-like polypeptide) causing a reduction in hunger and food intake in a study performed on 22 lean and 18 obese individuals.[113] PA promotes weight maintenance, due to its valuable effects on feeding behavior management utilizing decreased food cue reactivity within the brain reward areas. Increased participation in MVPA was linked with less brain response to high-calorie food cues after glucose consumption in regions involved in processing food rewards. The findings of this study are persistent with others, in that brain responses to food cues are shown to diminish after participating in exercise.[113]

The capability of exercise to promote predicted weight loss can be attenuated by several compensatory components.[85] It has been reported that individuals that do not tend to exercise report a prompt post-exercise desire for sweet foods that are high in fat, as well as a compensatory increase in caloric intake and hunger sensations.

HIIT promotes health benefits but it is not clear how HIIT impacts sedentary behavior. In a two-week exercise and counseling study conducted by Nugent et. al, the effects of supervised HIIT or moderate-intensity continuous training (MICT) were compared to sedentary time in overweight adults.[114] Participants included were thirty-two 30-60 year-old inactive females and males with prediabetes. Inactivity was based on less than two 30-min bouts of moderate-intensity PA per week. Participants were randomly assigned to the HIIT or MICT protocol of which included exercising 5 times per week for

a total of 10 training sessions. HIIT sessions were 1-min intervals that elicited ~90% peak heart rate, with 1-min rest intervals at a recovery pace with a warm-up cool-down integrated in before and after. These sessions began with 4 intervals and progressed to 10 intervals. The MICT sessions were continuous exercise at ~65% peak heart rate, starting with 20 minutes and proceeding to 50 minutes per session by the 10th day.[114]

Ten minutes of behavior change counseling was provided during each in-lab training day to the participants in both groups.[114] Participants wore an Actigraph GT1M accelerometer for 7 days pre-intervention, and 3 days during the exercise intervention. For this study sedentary behavior was stated as having more than 5 min with 0-99 counts per minute, with less than 1 min allowed outside of this range. It was found that planned, supervised HIIT leads to compensatory increases in sedentary behavior compared with MICT. Additionally, an increase in the percentage of wear time and minutes per day spent in MVPA during the exercise intervention in both the HIIT and MICT was linked with a decrease in the percentage of wear time spent in sedentary activity. It was inferred that this finding of time spent exercising during the intervention replaced the time formerly spent in sedentary activities. Overall it was found that participating in HIIT or MICT has no compensatory influence on sedentary behavior. However, these exercise bouts lead to a reduction in time spent in sedentary behavior during a 2-week intervention period in previously inactive overweight adults.[114]

Weight-loss related to energy deficits can be attributed to compensatory responses.[37] Strong affiliations have been noted between SB and elevated blood pressure as well as between sedentary time and increased waist circumference and BMI.[115] These discoveries suggest that less time being sedentary can lead to a decreased risk of CVD,

independent of MVPA time.[63] This causes a physiological hypothesis; SB is not solely the lack of exercise but has its own physiological ramifications that increase metabolic and cardiovascular risks, disregarding the time spent in PA. Furthermore, when compared to normal-weight inactive adults, overweight/obese adults who are active have lower chances of suffering from a cardiovascular incident and lower risk of chronic disease. This study concluded that there were no compensatory changes while participating in a combined diet and exercise intervention, SB did not increase and LIPA did not decrease, in overweight and obese individuals. However, after the intervention, %SB decreased and minutes in LIPA increased.[63]

Above all external factors, the success of a bariatric procedure is heavily reliant on the patient's desire to adhere to a healthier life, along with disciplined energy intake and PA.[116] This was concluded from an online survey conducted on 274 individuals who underwent RYGB surgery within the past 12 years. Patient's low self-reported dietary consistency in regards to grazing, mindless eating, loss of control eating, eating "more than is best" after dinner, eating food not on one's plan, and "when I eat something off-plan, I feel like I have blown it and I give up and eat more" leads to less weight loss.[22,116] Of these 6 maladaptive behaviors investigated, all were notably correlated with dietary adherence. Self-reported inadequate dietary adherence after a bariatric procedure is linked with a decrease in weight loss results.

The two most prevalent compensatory behaviors (CB) observed in a study conducted on 199 patients post gastric bypass were non-purging and fasting, respectively.[117] This study found the existence of CB is a modest but powerful predictor of a decreased BMI 6-months after surgery but did not continue at 12-months post-

surgery. The results state that pre-surgery CB has little to no effect on weight loss outcomes. In contrast, post-surgery CB may foretell longer-term weight loss outcomes.[117]

Hypotheses

The hypotheses are 1.) Postoperative bariatric subjects participating in a 12-week vigorous interval exercise intervention will increase their sedentary behavior and 2.) Postoperative bariatric subjects participating in a 12-week vigorous interval exercise intervention will increase their daily caloric intake.

Limitations/Delimitations

A limitation of this study was the geographical location of recruitment, with only one hospital in the area offering bariatric surgery to patients. Additionally, these patients may have already been participating in PA with or without a trainer before the study. The time required for wearing the micro ActivPals was seven consecutive days and this may have been too many days for the subjects or not enough for us to collect the data we needed. One other delimitation may lie in the motivation that the subjects felt for participating in the study.

Methods

Design

Post-operative bariatric participants were recruited to participate in a quasi-experimental study to identify compensatory behaviors during the 12-weeks of Vigorous-intensity Interval Training (VIIT). The exercise intervention along with pre-and post-measurements took place January 2018 through May 2018 on James Madison University's (JMU) campus. Written consent was obtained from all participants. This study was approved by the JMU Institutional Review Board.

Subjects

Participants who had undergone bariatric surgery within the past 6-24 months were recruited to join in the study. The recruitment was done through the social media webpage, Facebook, and personal contact with the Bariatric Surgery Department at Sentara-Rockingham Memorial Hospital. These post-operative bariatric participants were assigned to a VIIT protocol. Exclusion criteria included women who were pregnant, those with orthopedic limitations that would have inhibited their ability to complete the exercise intervention (such as moderate knee pain), or those with health conditions that placed them at high risk according to the American College of Sports Medicine (ACSM) guidelines. [118] Further evaluation to screen participants for medications, conditions, and/or injuries that may have impacted the participant's safety to partake in exercise was completed using the ACSM Risk Stratification for Cardiovascular Disease Risk and the Physical Activity Readiness Questionnaire (PAR-Q). If any question on the PAR-Q was marked "yes", physician approval was to be sought out to continue participation in the study.

Initial Visit

Research personnel met with eligible participants to obtain consent and explain the risks and benefits of the study. Participants completed two questionnaires, the Health-Related Quality of Life (HQOL) and the Physical Activity Enjoyment Scale (PACES). Participants were instructed to complete food intake records (FIR) on 4 consecutive days, three of which being weekdays and one weekend day. Additionally, participants received an ActivePAL accelerometer (AP) (PAL Technologies, Scotland, UK) which was programmed for 7 days using PALconnect. The AP was to be worn 7 consecutive days, at all times, and attached to the right upper thigh with Tegaderm adhesive tape. The AP was

used to quantify additional daily physical activities participants engaged in (walking, laying down, structured activity, standing) outside of the study's intervention. FIRs were to be filled out 5 times throughout the study (pre-intervention, week 3, mid, week 9, and post-intervention). APs were to be worn four times throughout the study (pre-intervention, week 3, week 9, and post-intervention). PACES and HQOL were filled out at pre-, mid, and post. Clinical and exercise testing occurred in pre, mid, and post-intervention.

Pre-Intervention Testing

Clinical Testing

Clinical testing included height and weight measurements, body composition, blood pressure (BP), and waist-to-hip ratio (WHR). Participants were instructed to remove their shoes to measure height and weight on a Med Vue Detecto Medical Weight Analyzer (Detecto, Webb City, MO). Body composition analysis was collected using a Dual Energy X-ray Absorptiometry (DXA) (Norland @ Swissray, Illuminatus DXA, Fort Atkinson, WI). BP was taken in the supine position immediately following the completion of the DXA scan to allow for an 8-12-minute rest before the measurement. Measurement of waist and hip girth was performed using a Gulick tape measure (Creative Health Services, Ann Arbor, MI). Waist girth was measured at the largest part of the buttocks and hip girth was measured at the narrowest point right above the navel. These measurements were used for the calculation of waist-to-hip ratio (WHR), which is used to determine body fat distribution. Also, body mass index (BMI) was calculated based on the participant's height and weight (kg/m^2).

Exercise Testing

For exercise testing, participants were required to fast without the consumption of caffeine or tobacco products three hours before attending testing, avoid heavy exercise the day before testing, and wear comfortable clothing. The submaximal exercise test was completed on a treadmill (Tuff Tread, Conroe, Texas) using a Parvo metabolic measurement system (Parvo) (Parvo Medics, Sandy Utah). The Parvo measured how much oxygen and carbon dioxide is utilized for muscle metabolism during exercise and calculates Respiratory Exchange Ratio (RER). Participants wore a Polar heart rate monitor watch and chest strap (Polar Electro Inc., Lake Success, NY) to monitor heart rate (HR). Participants were instructed to walk on the treadmill for a 5-minute warm-up at a self-selected pace of less than 2 mph, and then begin a modified Balke test. Stage one consisted of walking at 2mph with 0% grade for 2 minutes. The second stage consisted of 3 mph with 0% grade for 2 minutes. Each consecutive stage consisted of 3 mph with a progression of 2.5% for 2 minutes. BP, Rate of Perceived Exertion (RPE), and HR were recorded at the 1.5-minute mark of each stage. The protocol continued until the participant either reached 80-85% of their age-predicted heart rate max ($APHR_{max}$), experienced volitional fatigue, asked to stop, or experienced adverse signs or symptoms (ACSM). [118]

Protocol/Intervention

Familiarization Phase

After all initial measurements and testing, participants partook in 2-weeks of familiarization exercise to become acclimated to the treadmills. Each exercise session was 35-45 minutes, three times per week on non-consecutive days, for 12 weeks. The intervention took place Monday through Saturday with sessions occurring in the early morning or evening. Sessions consisted of 1-5 participants at a time on different

treadmills (LifeFitness, Rosemont, IL). For the 2-weeks of familiarization sessions, participants performed 5-minutes of dynamic stretches; Bosu ball wall squats, stationary marching, leg swings, wall push-ups, and calf raises. Participants were then prompted to warm-up on a treadmill for 5-minutes at a subjectively selected speed. After warming up, researchers increased either the incline, speed or both, based on the participant's preference until they reached 50% Heart Rate Reserve (HRR). This speed and grade were maintained for the rest of the 20-minutes during which, RPE, HR, speed, and incline were recorded every 4-minutes. Participants then performed a 5-minute cooldown on the treadmill and 6-minutes of cool-down stretches; forward and backward shoulder rolls, and oblique, hamstring, abductors, quadriceps, and calf stretches.

Phase 1

During phase 1, a duration of 4-weeks, all participants performed the previously described 5-minute dynamic warm-up and 5-minute warm-up walk on the treadmill. Participants exercised at 50% HRR for 4-minutes followed by 1-minute at 80% HRR, repeating this pattern 4 more times for a total of 20-24 minutes of exercise. HR, speed, grade, and RPE were recorded after each bout of exercise. The same cool-down protocol as the familiarization phase was completed. After the 6th week of exercise intervention, participants did not partake in the exercise intervention, due to mid-intervention clinical and exercise testing.

Phase 2

Throughout phase 2, a 6-week duration, the same warm-up protocol was followed. Participants exercised at 50% HRR for 3-minutes followed by 1-minute at 80% HRR, repeating this pattern 6 times for a total of 24-minutes. As previously stated, HR,

speed, grade, and RPE were recorded after any changes in HRR. Participants followed the same cool-down protocol as the familiarization phase. After the last week of this exercise intervention, post-intervention clinical and exercise testing was administered, and the last completed FIR and AP data were collected.

Analysis

All analyses were run through SPSS v.24 statistical software (IBM Corp, Armonk, NY, USA). AP data was uploaded on PAL Software (ActivePal3 Software v7.2.3). Food intake records were entered into the Nutrition Data System for Research (NDSR, University of Minnesota, 2012). Descriptive characteristics of participants included in the analyses are presented in Table 1. All data were assessed for normality before analyses. Due to data not being normally distributed, a non-parametric Wilcoxon sign-ranked test was used to compare the sedentary measurements of a single participant against the rest of the population. A paired-samples T-test was compared to all of the participant's pre-data to the post. A significance was set at a priori of $p > .05$.

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Compensation of Diet and Physical Activity During a 12-week Vigorous Interval Intervention in Post-Bariatric Men and Women

Kristen Byrne

Introduction

Globally, rates of severe obesity are increasing faster than any other disease, resulting in over 2.5 million obesity-related deaths, annually[1,2] Obesity is a risk factor for decreased mobility, cancers, cardiac disease, and high blood pressure.[3-5] Weight loss is possible if an individual implements positive compensatory behaviors (CB) by changing their behaviors, caloric intake, and physical activity (PA) habits. If changes are made, positive results can and will become evident. A decrease of as little as 2-3% of weight loss has been reported as beneficial in improving chronic disease risks in obese individuals.[3,6-10] A weight loss of this degree can create marked progress in risk factors for diabetes, heart disease,[3,4] some cancers and all-cause mortality, as well as a cessation of medications.[5,11-13] The effects of obesity on individuals are extensive and include decreases in self-efficacy, lack of exercise access, and a lack of motivation and/or behavior changes.[14-16] These often create a barrier to participating in physical activity (PA) and therefore increase sedentary behaviors (SB) adding to a revolving cycle of obesity.[17] Unfortunately, while this cycle of obesity continues, these individuals have tried to implement appropriate behaviors to improve body composition.

For severely obese individuals who have exhausted all other weight loss options, those at high risk for morbidity and mortality from weight-related comorbidities are eligible for bariatric surgery. Even with significant weight loss following surgery, this does not make the procedure a "miracle cure." Therefore, following surgery, patients benefit most from increasing PA and reducing time spent sedentary, both for health benefits and to reduce weight regain. As a result of the positive health effects, bariatric surgery has continued to grow in popularity; by the end of 2020, it is predicted that there will have been over a million bariatric surgeries performed.[18]

The National Institute of Health set qualifications of bariatric surgery at a BMI of ≥40 kg/m^2 without co-morbidities and for those with a BMI of ≥35 kg/m^2 with obesity-related complications, such as type 2 diabetes mellitus (T2DM), hypertension (HTN), and/or sleep apnea.[19-24] The potential effects of bariatric surgery are complicated and encompass several changes in, but not limited to, decreased caloric intake, behavioral instincts, weight control and GI hormonal responses [such as leptin and ghrelin].[25] The issue then arises not from a lack of perseverance but the sheer amount of change that is following a surgery.

Bariatric patients must endure lifelong regular evaluations and interventions as needed, to obtain and maintain optimal weight loss [26] and health benefits. While there are risks of complications, bariatric surgery promotes significant and prolonged effects on weight loss and decreases obesity-linked comorbidities in most bariatric patients.[18] The average weight loss following the first two years of all bariatric surgeries is 50-75% of excess weight.[27,28] This amount allows for the chance to regulate long-term weight and metabolic results, with near steady weight.[29] It is often found that those who undergo a weight loss procedure often participate in less PA than they did prior to surgery which in turn makes weight maintenance a difficult post-op task.[14] Therefore, despite the health benefits, the success of a bariatric procedure is heavily reliant on a patient's desire to adhere to a healthier lifestyle, and decrease negative CB.[19]

The existence of negative CB are a modest but powerful predictor of less weight loss, at 6-months after surgery, but not at 12-months post-surgery. Pre-surgery CB has little to no effect on weight loss outcomes, however, post-surgery CB may foretell longer-term weight loss outcomes.[30]

SB is defined as any waking behavior involving a sitting or lying position and/or the failure to achieve at least 20 minutes of PA at least three times per week.[31,32] There is a growing body of evidence that SB may be a distinct risk factor, independent of PA, for multiple adverse health outcomes in adults.[33] These health concerns include increased mortality, disease incidence, cardiovascular risk, blood pressure, waist circumference, and risk of developing type 2 diabetes mellitus.[33] Additionally, SB plays a part in post-surgery weight regain, as well as low PA levels, eating behavior disorders, and low QoL.[34] However, the post-operative patients who decide to change their behaviors and observed successful results are often not participating in increased SB.

Weight-loss related to energy deficits and increased PA can often be attributed to positive compensatory responses.[35] PA promotes weight maintenance with valuable effects in feeding behavior management, utilizing decreased food cue reactivity within the brain reward areas, and decreased sedentary behavior, all of which produce a decrease in hunger and food intake.[36] Lack of adherence to diet, assessed by self-report, is associated with worse weight loss results following bariatric surgery. To lower the possibility of weight regain, postoperative patients should increase their PA levels to preserve muscle mass and increase weight loss. A minimum of 60 minutes of moderate to vigorous physical activity (MVPA) daily, either consecutively or separately, has been shown to be adequate for maintaining weight loss.[14] Despite PA recommendations for weight loss control and avoidance of weight regain recommending moderate intensity PA,[37,38] smaller durations of vigorous activity may be adequate to obtain sufficient weight control.[39]

Guidelines show that all individuals can benefit from moving more and sitting less.[31] Those individuals that participate in the least amount of PA benefit most by even moderate increases in MVPA. Benefits have been found to be more related to the overall volume as opposed to bout length. HIIT promotes health benefits but it is not clear how HIIT impacts sedentary behavior. In recent studies, it has been found that participating in HIIT or MVPA has no compensatory influence on sedentary behavior.[16,40,41]

The majority of interval training studies performed thus far have only included general population participants. This may be due to time, physical capabilities, and/or other barriers that restrict the bariatric population to participate in a study. CB being assessed in this present study were amount of time spent sedentary and caloric intake throughout an exercise protocol. Therefore, the purpose of this study was to determine if participating in a 12-week VIIT intervention caused compensation, whether positive or negative, in time spent in sedentary behavior and caloric intake.

Methods

Design

Post-operative bariatric participants were recruited to participate in a quasi-experimental study to evaluate compensatory behaviors during 12-weeks of vigorous-intensity interval training (VIIT). This study was approved by the James Madison University Institutional Review Board and written informed consent was obtained from all participants prior to research testing.

Participants

Recruitment of participants was done through social media, bulk email, and personal contact with the Bariatric Surgery Department at Sentara-Rockingham Memorial Hospital, Harrisonburg, Virginia. The inclusion criteria for participation were a

bariatric surgical procedure performed in the past 6-24 months and ages 18-60. Exclusion criteria included those with orthopedic limitations that would inhibit their ability to complete the exercise intervention (e.g. knee pain), women who were pregnant, and/or those with health conditions that placed them at high risk according to the American College of Sports Medicine (ACSM) guidelines.[42] Further evaluation to screen participants for medications, health conditions, or injuries that may impact safety to participate in exercise was completed using the ACSM Risk Stratification for Cardiovascular Disease Risk and the Physical Activity Readiness Questionnaire (PAR-Q).[42,43] If any question on the PAR-Q was marked "yes," physician approval was required to participate in the study. Research personnel met with eligible participants to obtain consent and explain the benefits and risks of participating in the study.

Clinical Testing

Height and weight were measured using a Med Vue Detecto Medical Weight Analyzer (Detecto, Webb City, MO) and then used to calculate body mass index (BMI). Body fat percentage, lean body mass, and fat mass were analyzed using a Dual Energy X-ray Absorptiometry (DXA) (Norland @ Swissray, Illuminatus DXA, Fort Atkinson, WI). Measurement of waist and hip girth were performed using a Gulick tape measure (Creative Health Services, Ann Arbor, MI). Waist girth was measured at the largest part of the buttocks and hip girth was measured at the narrowest part right above the navel.

Exercise Testing

Participants were required to fast and refrain from caffeine or tobacco products three hours prior to testing and avoid heavy exercise the day before testing. The submaximal exercise test was completed on a treadmill (Tuff Tread, Conroe, Texas)

using a Parvo metabolic measurement system (Parvo) (Parvo Medics, Sandy Utah). Participants wore a Polar heart rate monitor watch and chest strap (Polar Electro Inc., Lake Success, NY) to monitor heart rate (HR). Using the ACSM guidelines, the Modified Balke Test was used as the procedure for the exercise testing.[44]

Protocol/Intervention

Familiarization Phase

Participants participated in 2-weeks of familiarization exercise to become acclimated to the treadmill. Sessions were three times per week on non-consecutive days, for 12-weeks. Participants performed 5-minutes of dynamic warm-up stretches; Bosu ball wall squats, stationary marching, leg swings, wall push-ups, and calf raises, followed by a subjectively selected warm-up speed on a treadmill for 5-minutes. Following the warm-up, researchers increased the incline and/or speed, based on the participant's preference until 50% Heart Rate Reserve (HRR) was reached. This speed and grade were maintained for 20 minutes during which RPE, HR, speed, and incline were recorded every 4-minutes. Participants then performed a 5-minute cool-down on the treadmill and 6 minutes of cool-down stretches; forward and backward shoulder rolls, and oblique, hamstring, abductors, quadriceps, and calf stretches.

Phase 1

During phase 1, a 4-week duration, all participants performed the 5-minute dynamic warm-up and 5-minute warm-up on the treadmill. Participants exercised at 50% HRR for 4-minutes followed by a 1-minute vigorous-intensity bout at 80% HRR, repeating this pattern a total of 4 times. HR, speed, grade, and RPE were recorded with prescribed percentage change in HRR. Following completion of the exercise protocol,

participants followed the cool-down protocol. Following this 4-week phase, all participants received one week off to participate in mid-intervention clinical and exercise testing.

Phase 2

During phase 2, a 6-week duration, all participants performed the 5-minute dynamic warm-up and 5-minute warm-up on the treadmill. Participants exercised at 50% HRR for 3-minutes followed by a 1-minute vigorous-intensity bout at 80% HRR, repeating this pattern for a total of 6 times. HR, speed, grade, and RPE were recorded with prescribed percentage change in HRR. Following completion of the exercise protocol, participants followed the cool-down protocol. After the last week of the exercise intervention, post-intervention clinical and exercise testing were performed, and the last completed FIR and AP data were collected.

Compensatory Behavior Assessment

Researchers educated participants on how to document a detailed food intake record (FIR). Participants were asked to complete five records throughout the study, each including four consecutive days (three weekdays and one weekend day) to assess dietary compensatory behaviors during the exercise intervention. Food Intake Records were analyzed using the Nutrition Data System for Research (NDSR, University of Minnesota, 2016). Researchers performed quality assurance on all FIR to check accuracy. Additionally, micro ActivPAL accelerometers (AP) (PAL Technologies, Scotland, UK) were given to participants four times throughout the study; pre, 3-weeks, 9-weeks, and post. The AP was programmed using PALconnect. The AP was to be worn seven consecutive days, at all times, and attached to the right upper thigh with Tegaderm

adhesive tape. The AP was used to objectively assess physical activity (walking, laying down, structured activity, standing) outside of the study. AP data was uploaded on PAL Software (ActivePal3 Software v7.2.3).

Analysis

All analyses were run with SPSS v.24 statistical software (IBM Corp., Armonk, NY). All data were assessed for normality, which resulted in a failed normality test. Data were then analyzed through the nonparametric Wilcoxon signed-rank test. The Wilcoxon signed-ranked test was used to compare the repeated measurements of a single participant against the rest of the population. A significance was set at *a priori* of $p > .05$.

Results

Fifteen participants began the intervention; 10 participants completed at least 85% of the exercise sessions (86.1-97.2%) and all study measures. Drop-out reasons included a non-study related injury, scheduling conflicts, family issues, and failure to attend the required number of exercise sessions. Participant characteristics are displayed in **Table 1**.

Despite addition of an exercise protocol, participants did not increase caloric intake, therefore it is determined that they did not engage in dietary CB. Additionally, they did not change macronutrient distribution, which can be seen in **Table 2**. There were no significant changes in weight or body composition, however, participants were able to maintain their weight throughout the study.

Participants did not compensate for additional exercise by increasing sedentary time outside of the study, nor did they increase their overall average step count as seen in **Figure 1** and **2**. Between the pre- and post-test data collection period, 4 participants increased their steps by an average of 12,120 steps in a week, while 4 decreased their

weekly steps by an average of 9,648 steps. **Figure 3** shows the average time spent in a standing position at all data collection periods. Due to technical difficulties with the AP, 2 participant's data were not recorded, therefore PA analyses were completed on 8 participants.

Discussion

The purpose of the current study was to assess compensatory behaviors in 6-24-month post-operative bariatric participants completing a 12-week VIIT program. The participants were successful at maintaining prior weight loss and did not show compensation of increased exercise intensity through diet or sedentary behavior. Given the well-documented benefits of PA and recent research indicating that benefits may be attainable with shorter, higher intensity bouts, this study's protocol may be a viable option for post-bariatric patients. This would allow post-operative patients to acquire the benefits with less time commitment.

To our knowledge, this is the first study to examine the effects of a 12-week VIIT program on compensatory behaviors in post-bariatric men and women participating in a physical activity only protocol study. Though there were no significant differences between pre- and post- weight measurements, it was found that participants were able to maintain their weight during a period of time that many patients begin to gain previously lost weight. [45,46] This current study's protocol did not require the recommended 90 minutes a day of exercise to maintain weight and there was no change in dietary habits and/or increase of steps throughout the week.[45] Our study revealed that less than two hours of vigorous intensity exercise a week weight can be maintained in post-operative

bariatric men and women. These findings could possibly be attributed to the mandatory supervised VIIT, three days a week, in addition to recording food intake.

Despite moderate intensity PA recommendations,[38] weight loss control and avoidance of weight regain with smaller durations of vigorous activity may be adequate to obtain sufficient weight control.[22] This finding corresponds with the current study, that three smaller durations of VIIT are sufficient in maintaining the participant's weight. Current exercise recommendations for weight control may seem overwhelming. It is often distressing to look at recommendations of 250 min of exercise a week to maintain/increase weight loss [21,47] – the reason we did interval training with this population was to determine if similar outcomes can occur in less time and participating in vigorous intensity intervals training. The time-efficient characteristics of a vigorous intensity exercise regimen are advantageous in developing a habitual strategic exercise plan for controlling weight. With the short duration of an exercise plan being implemented to maintain weight, individuals may not deem it necessary to compensate behaviors for the amount of time they spent moving.

Although the current study had a shorter duration and less participants, a similar 22-week diet and exercise study by King et. al, found that there were no significant CB changes in sedentary time observed or documented in 89 obese participants.[40] Likewise, in a 2-week exercise and counseling study by Nugent et. al, the effects of supervised HIIT or moderate-intensity continuous training (MICT) were compared to sedentary time in overweight adults. It was found that there was no compensation in sedentary time between the two varied intensities.[41]

Wing et al. revealed that recurring exercise [moderate intensity for a 12-week duration] has multiple effects, especially on appetite.[5] The outcome of this MICT versus HIIT protocol on appetite, in formerly sedentary obese individuals, does not seem to appear to differ. Both exercise procedures did not prompt significant changes in either subjective or objective appetite measures or food enjoyment, at least when weight loss is minimal.[5,31] In agreement with the preceding studies, our findings of no compensation in caloric intake and time spent sedentary can be extended to an additional population; post-bariatric men and women. However, it should be noted that King et al., Nugent et. al., and Wing et. al.'s studies did not include post-bariatric participants, but instead overweight/obese individuals. Ultimately, a strong correlation that was evident was weight loss and maintenance can be obtained when caloric intake it documented and even a short bout of exercise is implemented.

An underlying cause of poor weight loss post-bariatric surgery is disproportionate energy intake. It has been found that those who faithfully monitored their caloric intake managed a higher weight loss than those who infrequently self-monitored.[5] Postoperative CB, such as eating behaviors, are a crucial factor in the variation of weight loss. To preserve previously lost weight, postoperative patients need dietary control along with proper nutritional intake. Due to the FIR being a requirement of this current study, there is reason to believe this may have been the self-monitoring piece leading to weight maintenance.

There were a few limitations of this study that the researchers would like to address. The study included a homogenous population and a small sample size. Five participants dropped out of the study due to challenges not related to the study design.

Second, we were not able to ascertain the previous weight loss from the bariatric surgery procedure. Lastly, recall bias may have impacted the food intake records. Participants were provided detailed instructions and guidance on how to complete their diet records, but dietary recall bias often presents itself with measurements and food products.

Further research is needed on the qualitative side of this study. While the main focus of this study was to determine if VIIT alters compensatory behaviors, participants verbally reported to researchers that they were experiencing mental health improvements. This was noted in ways of decreased medication dosages for both anxiety and depression, and overall feeling more energetic.

As the next step to clearly define the potential for reduced exercise time intervals to provide additional health benefits following bariatric surgery, additional randomized controlled exercise trials are needed. Researchers should consider combining a 12-week VIIT protocol in conjunction with a dietary counseling intervention. This would allow for specific times allotted for education on healthy diet practices following surgery along with participating in PA, potentially leading to weight loss rather than maintenance. Dietary control is needed for several reasons to help postoperative patients; increasing patient's adherence to healthy habits, routine intake of supplementation, and preservation of previously lost weight.[20] This was found in a study focusing on weight loss strategies reviewing the consequences of a diet and exercise intervention versus a diet-only intervention on both short-term and long-term weight loss.[48] Compared to a diet only program, a combined diet and exercise program produced an increased long-term weight loss, especially in longer interventions. Future studies involving larger sample sizes allowing for testing of potential moderators (e.g., sex, age), with longer intervention

periods, are needed to conclusively determine from our preliminary findings that post-bariatric participants do not compensate a VIIT protocol with increased sedentary time and/or increased caloric intake.

In summary, contrary to typical patterns of weight regain in post-operative bariatric patients, our participants were able to maintain weight. These findings indicate that a short-term supervised exercise intervention, performed as VIIT, has no compensatory impact on sedentary behavior or diet, but it is possible to maintain previous weight lost.

Tables

Table 1. Post-operative Bariatric Body Composition of Participants Completing a 12-week Vigorous Intensity Interval Training Protocol

n=10 (Female = 9)	Pre	Post
Age (years)	52.75 ± 3.75	
Height (cm)	164.59 ± 3.77	
Mass (kg)	88.68 ± 8.76	88.99 ± 8.84
BMI (kg/m^2)	33.65 ± 2.90	33.76 ± 2.93
WHR	0.81 ± 0.04	0.81 ± 0.04
Fat Mass (kg)	40.84 ± 5.09	41.24 ± 5.12
Fat Free Mass (kg)	51.84 ± 5.15	51.42 ± 5.45
Lean Mass (kg)	48.41 ± 5.17	48.50 ± 5.30
Body Fat (%)	44.00 ± 2.38	42.95 ± 3.01

WHR = Waist to Hip Ratio

Table 2. Food Intake and Macronutrient Distribution of Post-operative Bariatric Participants Completing a 12-week Vigorous Intensity Interval Training Protocol

	Pre	3wk	6wk	9wk	Post
Caloric intake	1546.8 ± 608.1	1507.7 ± 731.3	1487 ± 592.9	1551.4 ± 734.1	1405.3 ± 525.4
Macronutrient Intake (g/day)					
Carbohydrate	127.6 ± 54.1	135.2 ± 54.1	117.1 ± 47.5	129.5 ± 41.3	123.5 ± 35.8
Protein	87 ± 35.7	70 ± 26.9	85.4 ± 31.1	75.1 ± 26.9	74.4 ± 30.9
Fat	71.5 ± 26.2	67.5 ± 34.7	68.1 ± 21.2	76.1 ± 47.1	61.4 ± 26.5
Dietary composition (% of Caloric Intake)					
Carbohydrates	28.7 ± 12.3	35.4 ± 8.3	29.7 ± 7.9	33.7 ± 8.9	35.7 ± 11.1
Protein	23.3 ± 6.3	20.9 ± 6.4	23.8 ± 4.8	20.4 ± 3.7	21.4 ± 2.4
Fat	41 ± 5.7	39 ± 6.6	41.4 ± 6.8	41.9 ± 6.6	38.1 ± 9.3

Food intake record data on caloric intake and macronutrient distribution for all data collection periods in 10 participants.

Figures

Figure 1. Distribution of Post-operative Bariatric Participant's Time Spent in a Sitting/lying Position During a 12-week Vigorous Intensity Interval Training Protocol

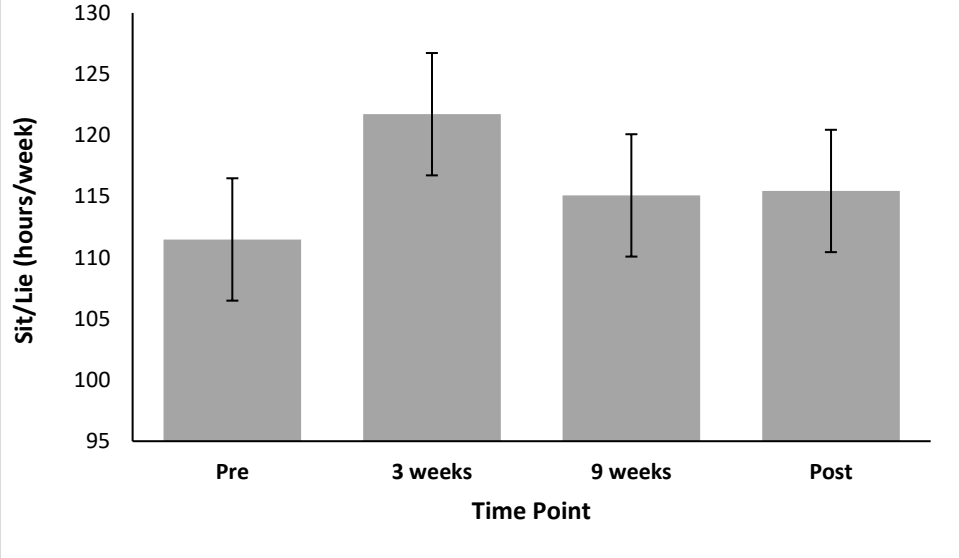


Figure 2. Distribution of Post-operative Bariatric Participant's Steps During a 12-week Vigorous Intensity Interval Training Protocol

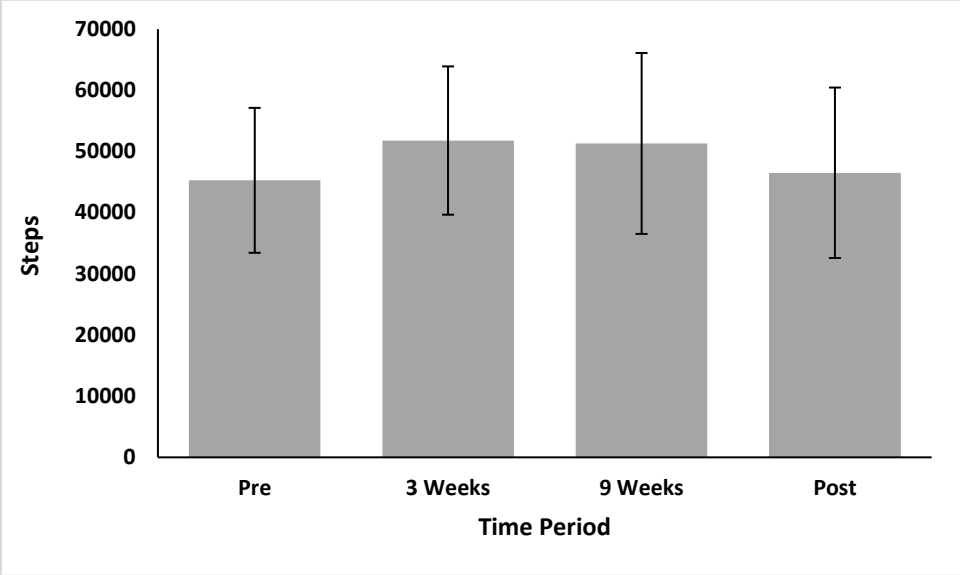
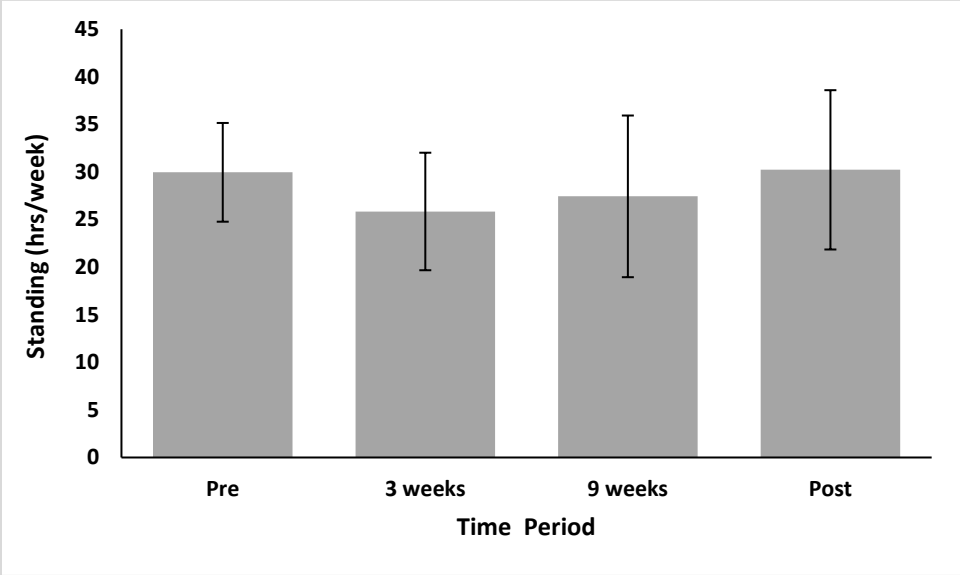


Figure 3. Distribution of Post-operative Bariatric Participant's Time Spent Standing During a 12-week Vigorous Intensity Interval Training Protocol



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