THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY, PHYSICAL FUNCTION AND PSYCHOSOCIAL VARIABLES IN INDIVIDUALS POST-BARIATRIC SURGERY

by

Deborah Ann Josbeno

B.S. Daemen College, 1985

M.S. University of Pittsburgh, 1996

Submitted to the Graduate Faculty of

The Department of Health and Physical Activity in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2009

UNIVERSITY OF PITTSBURGH

SCHOOL OF EDUCATION

This dissertation was presented

by

Deborah A. Josbeno

It was defended on

April 17, 2009

and approved by

Melissa Kalarchian, PhD., Associate Professor, Department of Psychiatry

Patrick Sparto, PhD., Associate Professor, Department of Physical Therapy

Amy Otto, PhD., Associate Professor, department of Health and Physical Activity

Dissertation Advisor: John M. Jakicic, PhD., Professor/Department Chairperson, Department of Health and Physical Activity

THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY, PHYSICAL FUNCTION AND PSYCHOSOCIAL VARIABLES IN INDIVIDUALS POST-BARIATRIC SURGERY

Deborah A. Josbeno, PhD

University of Pittsburgh, 2009

The incidence of morbid obesity (BMI $\geq$ 40 kg•m^{-2}) is increasing at an exponential rate. Currently, the most viable option for weight loss is bariatric surgery. Success following surgical procedure is guided by the individual's ability to make behavioral changes. A better understanding of physical activity behavior of individuals who undergo bariatric surgery will enable the development of effective post-surgical exercise guidelines and interventions to enhance surgical weight loss outcomes. **PURPOSE**: To define the physical activity profile of subjects 2-5 years post bariatric surgery by examining the relationship between physical activity and weight loss. Additionally, this study examines the association between physical function, psychosocial correlates of physical activity, and weight loss. **METHODS:** Thirty-seven adults (percentage excess weight loss (%EWL) = 62.15 ±19.93, age = 50.76 ±9.99 years) participated. Subjects wore an activity monitor to measure their physical activity. Body height, weight, physical function, psychosocial variables of physical activity (self-efficacy, expected outcomes (benefits) and perceived barriers) and health related quality of life were measured. Assessment also included demographics, medical history, and dietary questionnaires. **RESULTS:** This study determined that subjects' who have undergone bariatric surgery participated in 205.33 ±136.98 minutes per week of $\geq$ 3METs for $\geq$1 minute bouts. The average dropped to 47.56 ± 69.84

minutes per week when including only bouts of 10 continuous minutes or more. Physical activity was correlated with %EWL ($r=0.47$, $p=<0.01$) and self-efficacy ($r=0.39$, $p<=0.02$), but not with physical function, expected outcomes (benefits), perceived barriers, or HRQOL. Physical function was correlated with %EWL ($p<0.05$). **CONCLUSIONS:** The subjects' activity level failed to meet standards that have been shown necessary for weight maintenance. Those subjects that were more confident in their ability to exercise were more active and had more success losing weight. These findings suggest that behavioral interventions should include a strategy to address self-efficacy. The disparity between physical activity and physical function would suggest that subjects are capable of performing most mobility activities. Future research should focus on exercise interventions that address self-efficacy and other behavioral barriers (e.g. musculoskeletal pain and psychosocial factors) with the goal of maximizing post surgical weight loss success.

TABLE OF CONTENTS

PREFACE XII

1.0 INTRODUCTION 1

1.1 STATEMENT OF PROBLEM 3

1.2 SPECIFIC AIMS 4

1.3 SIGNIFICANCE 5

2.0 REVIEW OF LITERATURE 6

2.1 PREVALENCE AND HEALTH CONSEQUENCES OF OBESITY 6

2.1.1 Effects of weight loss on health consequences of obesity 8

2.2 BARIATRIC SURGERY 9

2.2.1 Surgical procedures 10

2.2.2 Complication of bariatric surgery 12

2.2.3 Benefits of bariatric surgery 13

2.2.3.1 Reduction in mortality 13

2.2.3.2 Reduced morbidity 14

2.2.4 Long-term impact of bariatric surgery 15

2.3 IMPORTANCE OF PHYSICAL ACTIVITY 17

2.3.1 Physical activity and weight loss maintenance within behavioral interventions 17

2.3.2 Physical activity for weight loss maintenance post- bariatric surgery... 19
2.3.3 Exercise adherence and weight control.. 20
2.3.4 Psychosocial factors affecting physical activity participation 21
2.4 PILOT STUDY. THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY, PHYSICAL PERFORMANCE AND PSYCHOSOCIAL VARIABLES IN INDIVIDUALS S/P GASTRIC BYPASS SURGERY 23
2.5 CONCLUSION 25
3.0 METHODS 27
3.1 REASEARCH DESIGN 27
3.2 SUBJECTS 27
3.3 RECRUITMENT PROCEDURES 28
3.4 ASSESSMENT PROCEDURES 31
3.4.1 Demographics questionnaire.. 33
3.4.2 Medical history questionnaire 33
3.4.3 Dietary intake 33
3.4.4 Body weight, height, and BMI 33
3.4.5 Physical activity.. 34
3.4.6 Perceived physical function.. 35
3.4.7 Psychosocial correlates of physical activity 36
3.5 STATISTICAL CONSIDERATIONS AND POWER ANALYSIS 36
4.0 RESULTS 39
4.1 SUBJECTS CHARACTERISTICS 39
4.2 PHYSICAL ACTIVITY 43

4.3 PHYSICAL FUNCTION 48
4.4 PSYCHOSOCIAL VARIABLES 50
5.0 DISCUSSION 55
5.1 INTRODUCTION 55
5.2 PERCENT EXCESS WEIGHT LOST 56
5.3 SPECIFIC AIM 1: TO DESCRIBE PHYSICAL ACTIVITY LEVELS (MINUTES/WEEK OF MODERATE TO VIGOROUS ACTIVITY) IN INDIVIDUALS 2-5 YEARS POST BARIATRIC SURGERY. 56
5.4 SPECIFIC AIM 2: TO EXAMINE THE ASSOCIATION BETWEEN LEVEL OF PHYSICAL ACTIVITY AND LEVEL OF WEIGHT LOSS IN INDIVIDUALS 2-5 YEARS POST BARIATRIC SURGERY. 58
5.5 SPECIFIC AIM 3: TO EXAMINE THE ASSOCIATION BETWEEN PHYSICAL FUNCTION AND PHYSICAL ACTIVITY IN INDIVIDUALS 2-5 YEARS POST BARIATRIC SURGERY. 60
5.5.1 Specific Aim 4: To examine the association between physical function and amount of weight loss in individuals 2-5 years post bariatric surgery. 62
5.6 SPECIFIC AIM 5: TO EXAMINE THE ASSOCIATION BETWEEN PSYCHOSOCIAL VARIABLES OF PHYSICAL ACTIVITY AND LEVEL OF PHYSICAL ACTIVITY IN RESPONSE TO BARIATRIC SURGERY. 63
5.7 LIMITATIONS AND FUTURE RESEARCH 66
5.8 CONCLUSION 69
APPENDIX A 71
APPENDIX B 72

APPENDIX C **74**

APPENDIX D **75**

APPENDIX E **77**

APPENDIX F **79**

APPENDIX G **80**

APPENDIX H **81**

APPENDIX I **83**

APPENDIX J **84**

APPENDIX K **85**

BIBLIOGRAPHY **86**

LIST OF TABLES

Table 1: Common nutritional complications after bariatric surgery 13

Table 2: Study Timeline... 32

Table 3: Demographic Characteristics 41

Table 4: Frequency of co-morbidities 42

Table 5: Frequency of surgical complications 43

Table 6: Recall of physical activity recommendations 43

Table 7: Descriptive data of physical activity when defined using different criteria 45

Table 8: Descriptive data of psychosocial variables and HRQOL 49

Table 9: Correlations between physical activity and psychosocial variables 51

Table 10: Comparison of variables between subjects grouped according to physical activity 52

LIST OF FIGURES

Figure 1: Surgical procedures 11

Figure 2: Self-reported level of physical activity 24

Figure 3: Self reported perceived physical function 24

Figure 4: Performance-based physical function 25

Figure 5: Total time spent at various intensities and durations 45

Figure 6: Relationship between physical activity, physical function and %EWL 46

Figure 7: %EWL based on categories of physical activity participation 47

Figure 8: Physical function based on categories of physical activity participation 49

Figure 9: Correlation between physical activity and %EWL 77

Figure 10: Correlation between physical activity & %EWL 78

Figure 11: Correlation between physical activity and physical function 79

Figure 12: Correlation between physical function and %EWL 80

Figure 13: Correlation between physical activity and self-efficacy 81

Figure 14: Correlation between physical activity and self-efficacy 82

Figure 15: Correlation between physical activity and psychological benefits 83

Figure 16: Correlation between physical activity and time barrier 84

Figure 17: Correlation between physical activity and HRQOL 85

PREFACE

I would like to express my gratitude to my committee members for their guidance and support throughout this journey.

Dr. John Jakicic, my advisor and mentor, I am grateful for your genuine interest and enthusiasm you have expressed throughout this project. Thank you for your constant support and patience. Dr. Melissa Kalarchian, thank you for providing your expertise in behavioral interventions and letting me be a part of your research team. Dr. Amy Otto, your expertise with dietary intake and your suggestions were always helpful and welcomed. Dr. Patrick Sparto, thank you for always providing me with valuable feedback throughout the course of this project. It was a privilege to have you all on my committee and I appreciate your efforts on my behalf.

I owe a debt of gratitude to the RENEW research staff that willingly helped me with participant recruitment: Meredith, Betsy, Gina, Meghan, and Carrie -- I could not have done this without your help. I am also extremely grateful to Dr. George Eid, Dr. Ramesh Ramanathan and Dr. Anita Courcoulas. Without their support and the support of their office staff my ability to recruit patients would have been much more difficult.

I would like to thank my colleagues and friends in the Physical Therapy Department for their continued support and guidance. Everyone has played an important part in this accomplishment and I feel lucky to be surrounded by such a great group of colleagues and

friends. In particular, I owe special acknowledgment to Dr. Anthony Delitto who was more than supportive throughout this entire process and who always gave me the latitude to pursue my goals.

Heartfelt thanks go out to my colleague and good friend, Dr. M. Kathleen Kelly, who was always there to provide me with much needed encouragement and invaluable feedback. Without your support this task would not have been impossible.

I also want to recognize my incredible network of friends whose unwavering support has been a blessing through this process. I would especially like to express my sincere gratitude to MC for his constant encouragement and unselfish support during the home stretch. I could not have done this without his calmness and patience at just the right time.

Lastly, to my parents who instilled in me the determination to succeed. I thank them for their endless encouragement and support throughout my entire life. You are my role models both personally and professionally. This dissertation is dedicated to the both of you.

1.0 INTRODUCTION

Obesity is a chronic and debilitating condition plaguing our society with >30% of adults being considered obese; even more troubling is the increasing prevalence of Class III obesity (defined as having a BMI$\geq$ 40 kg•m^{-2}) (1-3). Class III or extreme obesity, is increasing twice as fast as obesity and affects almost 1 in 20 adults in the United States (3;4). Class III obesity is associated with greater risk of morbidity and mortality from chronic health conditions such as type 2 diabetes mellitus, cardiovascular disease and hypertension and is also associated with physical disability and poorer quality of life (5-15). This increased prevalence has resulted in an exponential increase in bariatric surgery with the most commonly performed procedure being Roux-en-Y gastric bypass surgery (GBS) and gastric banding (GB) (16-18).

Currently there is evidence to support the effectiveness of weight loss and the improvements or reduction of co-morbidities associated with obesity in the short term, but there is limited data on long-term weight loss with these surgeries (16;19-24). Patients typically lose 65-80% of their excess body weight (EBW) following GBS. The peak of this weight loss is usually between 12-18 months and generally levels off by 2 years. Weight loss after GB generally progresses over a 2 to 3 year time span and stabilizes between 40-60% excess weight lost (EWL) (23;25-27). Despite the fact that most people lose a significant amount of weight, emerging data is suggesting that an ample amount of patients have weight regain and the return of co-morbidities in the long-term (16;23;24;28-30).

The scientific community is just beginning to understand the long-term impact on bariatric surgery and factors leading to poor surgical outcomes. Failure to lose a significant amount of weight as well as weight regain have typically been attributed to poor adherence to post operative modifications such as limiting caloric intake and increasing energy expenditure. Most research has focused on examining eating behaviors after surgery (such as dietary adherence and eating disorders) (31-35), but there has been relatively little investigation of physical activity behavior of bariatric surgery patients and how factors of physical activity contribute to long-term surgical outcomes (20;29).

Physical activity has been shown to be a key component of successful weight loss and maintenance for overweight and obese individuals following a standard behavioral weight loss program (36-38). To prevent weight regain for previously overweight and obese individuals, 60-90 minutes of moderate intensity physical activity on most days is recommended (38). However, the role of physical activity in weight loss and maintenance among those who had bariatric surgery is not known. Recent preliminary studies suggest that success following bariatric surgery is influenced by the individual's ability to make lifestyle changes including physical activity modifications but these studies have relied on retrospective self-report measures of physical activity and did not include objective measures of physical activity participation (39;40). Currently there is minimal information characterizing the physical activity levels in those individuals that are successfully maintaining weight loss after bariatric surgery and those who have regained weight. Furthermore, there is limited information regarding adherence to physical activity recommendations in this population. Little is known about factors that can predict which individuals will adopt and maintain physical activity as part of their weight loss treatment, and even less is known about psychosocial factors (e.g. self-efficacy, barriers, etc.) that may be predictive of and/or associated with the adoption and maintenance of physical activity/exercise in this population.

Targeting specific psychosocial factors related to physical activity may enhance weight loss. Association between physical activity and factors such as self-efficacy, social support, ratings of perceived benefits and barriers have been observed in several studies (41-44). Gallagher et al studied the effects of a 6 month behavioral intervention on psychosocial variables of physical activity and stated that participants who reported higher levels of physical activity and ≥10% weight loss also reported higher levels of physical activity self-efficacy, greater use of behavioral strategies to elicit social support, and fewer barriers to physical activity (45). However, evidence concerning the influence of psychosocial factors on physical activity participation in individuals who have undergone bariatric surgery has not yet been studied.

Consequently, a better understanding of the physical activity data of the individuals who undergo bariatric weight loss surgery may contribute to the development of effective post surgical exercise guidelines and could lead to improved weight loss and surgical success.

1.1 STATEMENT OF PROBLEM

Due to the peak weight loss occurring between 18-24 months after GBS this study focused on a time frame 2-5 years post bariatric surgery. Currently there is very little information on the physical activity patterns in individuals who are 2-5 years post bariatric surgery. There is also little information on the barriers and determinants of physical activity among individuals who are 2-5 years post weight loss surgery. The purpose of this study was to characterize the physical activity profile of the participants between the 2-5 years post bariatric surgery. These characteristics included: level of physical activity, self reported physical function and psychosocial factors associated with physical activity (self-efficacy, outcome expectations, perceived barriers, and health related quality of life (HRQOL)).

1.2 SPECIFIC AIMS

This study specifically examined the following:

Specific Aims:

1. To describe physical activity levels (minutes/week of moderate to vigorous activity) in individuals between 2-5 years post bariatric surgery.
2. To examine the association between level of physical activity and level of weight loss in individuals between 2-5 years post bariatric surgery.

   Hypothesis: It is hypothesized that individuals who have the most weight loss between 2-5 years post bariatric surgery will participate in the greatest level of physical activity 2-5 years post bariatric surgery.
3. To examine the association between physical function and physical activity in individuals between 2-5 years post bariatric surgery.

   Hypothesis: It is hypothesized that individuals who have a greater level of physical activity will report a greater level of physical function 2-5 years post bariatric surgery.
4. To examine the association between physical function and amount of weight loss in individuals between 2-5 years post bariatric surgery.

   Hypothesis: It is hypothesized that individuals who report a greater level of physical function will have greater weight loss 2-5 years post bariatric surgery.

5. To examine the association between psychosocial correlates of physical activity and level of physical activity in response to bariatric surgery.

   Hypothesis: It is hypothesized that individuals who report fewer perceived barriers to physical activity, greater self-efficacy for physical activity and higher HRQOL will have participated in a greater level of physical activity 2-5 years post bariatric surgery.

1.3 SIGNIFICANCE

The number of individuals who are morbidly obese (BMI $\geq$40 kg•m^{-2}) is increasing at a rapid rate and the treatment of this condition continues to be a major challenge. Currently the most viable option for weight loss for these individuals is bariatric surgery. Success following surgical procedures is guided by the individual's ability to make behavioral changes such maintaining an active lifestyle. The 2005 Dietary Guidelines provide guidelines for weight loss maintenance stating that adults need an estimated 60-90 minutes/day of moderate activity to avoid weight regain (46). However, there are no current physical activity recommendations for this population. A better understanding of the relationship of physical activity behaviors and attitudes to physical activity participation following bariatric surgery will enable the development of effective post-surgical exercise guidelines and interventions to enhance surgical outcomes. Thus, this study proposed to define a physical activity profile of the subjects between 2-5 years post bariatric weight loss surgery by characterizing their physical activity participation and examining the relationship of the level physical activity and level of weight loss. Additionally, this study examined the association between physical function and psychosocial correlates of physical activity and level of physical activity in subjects 2-5 years post bariatric surgery.

2.0 REVIEW OF LITERATURE

The primary purpose of this study was to define a physical activity profile of the subjects between 2-5 years post bariatric surgery by characterizing their physical activity participation and examining the relationship of the level physical activity and level of weight loss. Additionally, this study examined the association between physical function and psychosocial correlates of physical activity level and level of physical activity in subjects 2-5 years post bariatric surgery. This chapter provides a review of the related literature supporting the significance and rationale of this study.

2.1 PREVALENCE AND HEALTH CONSEQUENCES OF OBESITY

The prevalence of obesity (BMI $\geq$30 kg•m^{-2}) in the United States has increased significantly and has become a major health problem (2;47;48). It is estimated that approximately 65% of the adult population is either overweight (BMI = 25 to 29.9 kg•m $^{-2}$) or obese (BMI $\geq$30 kg•m^{-2}), with 4.7% of adults having Class III obesity (BMI $\geq$40 kg•m^{-2}) (2). The prevalence of Class III has quadrupled in the last decade (3;4). This increasing trend has created difficult challenges for the healthcare system and warrants greater attention.

There are medical, physical, psychological and social co-morbid conditions associated with presence of excess body weight (49). Obesity is associated with greater risks of morbidity and mortality from chronic health conditions such as type 2 diabetes mellitus, cardiovascular disease and hypertension (5-8;15) and poorer quality of life (13;14). In addition, obesity has been linked to physical impairments such as changes in specific gait kinematics, musculoskeletal joint pain (knee, hip, foot and low back), and increased energy expenditure during walking leading to mobility limitations (9-12;50).

Studies have shown that higher levels of BMI are associated with lower levels of physical activity (51;52). When compared to a normal weight population obesity was associated with greater risk of physical function decline (53). Kolotkin et al reported that morbidly obese persons commonly self-report that weight has a negative impact on mobility, physical activity and performance of activities of daily living (ADLs) (54). A decline in physical function can greatly impact one's ability to carry out ADLs in a safe and efficient manner. Furthermore, a decline in physical function has been shown to contribute to inactivity (both leisure time activity and activities of daily living), thus promoting an unhealthy lifestyle and contributing to the burden of disability (55;56).

Several studies have found that obesity increases the risk of physical disability with middle aged and older adults (11;57-59). In a retrospective study, Stenholm et al reported that obesity was predictive of walking limitations at age 65. For example, there was an increased odds ratio (OR) of having limitations in walking disability at the age of 65 if the individual was obese at age 30. Moreover, if obese at age 50, the OR for the presence of mobility limitations (unable to walk 400 meters or climb 10 steps) at the age of 65 increased to 4.33 (60). Alley et al examined ADL performance and mobility limitations in older adults (age $\geq$ 60) from data collected as part of the National Health and Nutrition Examination Survey (NHANES 1998-2004). Results showed that obese older adults are at 2-3 fold higher risk of mobility limitations, where ADL performance was not as limited (56).

Obese adults have also been shown to have a lower aerobic capacity relative to their body weight compared to normal weight counterparts. Mattsson et al showed that the oxygen consumption (VO_2) of obese women who walked at a self-selected pace for 4 minutes was 56% of maximal capacity; however, this corresponded to unusually high reported levels of perceived exertion (61). Browning et al studied energy cost of walking of obese and non-obese subjects and reported that preferred walking speed for obese individuals was slower than that of age-matched non-obese individuals (1.40 m/sec versus 1.47 m/sec) with relative intensity being higher in obese versus non-obese subjects (51% versus 36%) of maximal VO_2 resulting in a higher energy cost (62). Furthermore, Larsson et al reported that obese women perceived and demonstrated greater disability in tasks such as personal hygiene, ADL performance, housework that required squatting or lifting, walking and stair climbing compared to normal weight women (9).

2.1.1 Effects of weight loss on health consequences of obesity

Weight loss has been shown to decrease the risk for many co-morbid conditions associated with excess body weight (63). Behavioral approaches to weight loss have traditionally focused on reductions in energy intake through diet and increases in energy expenditure through exercise. This approach has typically resulted in an 8 to 10% reduction of initial weight during a 4-6 month weight loss program, with 66% of weight loss maintained at one year. However, at 5 years most individuals have regained to near baseline levels of body weight (23;64). Pharmacologic agents are available to be used in conjunction with diet and exercise, and weight loss with this approach being approximately 10% of initial body weight (65). Thus, alternative therapies may be required to improve weight loss beyond this level that can be achieved with either standard behavioral or pharmacological approaches.

Surgical interventions may be an effective treatment that yields weight loss and reductions in co-morbid conditions associated with obesity (66). The Swedish Obese Subjects

(SOS) study compared weight loss surgery to a conservative non-surgical treatment in a matched-pair design. The surgical group consisted of 2010 subjects who underwent bariatric surgery (gastric banding, gastroplasty, or gastric bypass surgery). The majority of the subjects underwent gastroplasty and only a limited number of subjects underwent gastric bypass surgery. The conservative non-surgical group received usual care for obesity which may have included dietary advice, behavioral modifications, very low caloric diet, physical training, pharmaceutical treatment or no treatment provided (19;67). Results showed that subjects lost significantly more weight after surgical treatment compared to conservative non-surgical treatment approach. In the surgical group the maximum weight loss was 25.3% at 1 year. At 10 years post-surgery 12% of subjects lost ≥ 30% of their baseline weight, one-fourth lost 20.0% of baseline weight, one-third lost 10-19.9% of baseline weight, approximately one-fourth lost < 10% of baseline weight, and 9% of the subjects gained weight. Conversely, in the conservative treatment group, the average weight lost was 1.2% after 6 months. The weight loss was regained after 2 years and an average weight increase of 1.5% observed after 10 years. This difference in weight loss between the conditions resulted in decreased incidence of co-morbidities such as diabetes, hypertension, sleep apnea and dyspnea when climbing stairs in the surgical group. This study also found health related quality of life (HRQOL) to be directly associated with weight loss (19;67). Thus, bariatric surgery has been shown to effectively reduce medical complications of obesity (16;68-70).

2.2 BARIATRIC SURGERY

The increasing prevalence of Class III obesity together with the development of laparoscopic procedures has led to a steep rise in the number of bariatric weight loss surgeries performed in the United States. From 1998 to 2004 there was a nine fold increase in the total number of bariatric surgeries performed in the United States, from 13,386 to 121,055 (71). Based on the NIH Consensus Development Panel, surgical intervention is offered to adult individuals who have failed attempts at non-surgical weight loss, have a BMI $\geq$ 40 kg•m^{-2}, or a BMI $\geq$35 kg•m^{-2} with co-morbidity. However in 2004, the American Society of Metabolic and Bariatric Surgery (ASMBS) Consensus statement included consideration for those with a BMI from 30-34.9 kg•m^{-2} with co-morbid conditions that can be improved by substantial weight loss (72). Bariatric surgery is increasingly being performed on adolescents and older adults, and recent data has suggested that surgery in these age groups is as effective as what has been shown in adults (73;74).

2.2.1 Surgical procedures

Bariatric surgical procedures include the following: 1) biliopancreatic diversion (BPD) 2) gastric banding (GB), 3) gastric bypass (GBS) (Figure1). Most of these procedures are performed laparoscopically using minimally invasive techniques. GBS is the most frequently performed bariatric procedure in the United States, but GB is gaining worldwide popularity (17). However, BPD may produce weight loss that is superior to both GB and GBS, but BPD has been reported to have greater incidence of medical complications. Therefore, there does not appear to be consensus on which procedure is optimal. In practice, the choice of procedure is most likely tailored to the patient's BMI, perioperative risks and co-morbidities, and surgeon's preference.

<u>Diversionary Malabsorption Procedure:</u> BPD is a diversionary malabsorption procedure that resects the stomach and bypasses long segments of the small intestine reducing the area of mucosa available for nutrient absorption. This procedure promotes selective malabsorption of fat and results in effective loss of weight. However, this procedure carries the greatest incidence

of post-surgical complications such as protein malabsorption, diarrhea, and vitamin deficiencies due to the alterations in the intestinal tract. This procedure is illustrated in Figure 1, Panel A.

Gastric Banding (GB): GB is a restrictive surgical procedure commonly performed in Europe and Australia but in recent years has gained increasing popularity in the United States. This procedure involves the placement of a small, adjustable ring around the gastric cardia of the stomach creating a small pouch. Weight loss results by this procedure limiting the capacity of the stomach to accommodate food and by slowing down the flow of ingested nutrients through the digestive process. This procedure is illustrated below in Figure 1, Panel B.

Gastric Bypass (GBS): GBS surgical procedures result in a reduction of the stomach to approximately 5% of its normal volume and a bypass of remainder of the stomach and a portion of the small intestine (includes the duodenum and approximately 20 cm of the proximal jejunum) (68;75-77). Thus, GBS generates weight loss by limiting the capacity of the stomach to accommodate food and by reducing the digestive capacity of the small intestine, which results in mild malabsorption. Weight loss typically peaks by 12 to 18 months post-GBS and generally levels off at 2 years. This procedure is illustrated in Figure 1, Panel C.

A B. C.

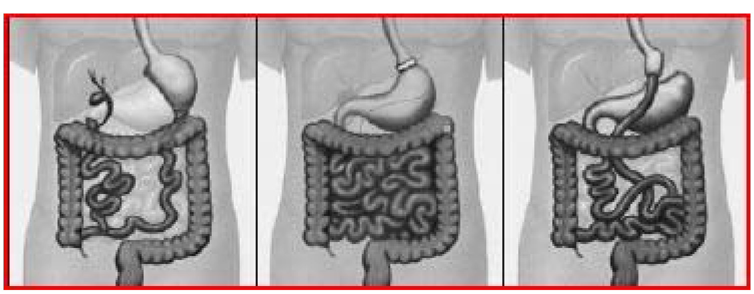

Figure 1: Surgical procedures

A, Biliopancreatic diversion. B, Adjustable gastric banding; C, Roux-en-Y gastric bypass; (Adapted from ***Identification and Treatment of Extreme Obesity-Considering Surgical Options: Frequently Asked Questions,*** August 2007). Reproduced with permission of SynerMed® Communications

Weight loss after bariatric surgery is most commonly expressed as the percentage of excess body weight lost (%EWL). Excess weight is the weight of a person minus the person's ideal body weight, with the ideal body weight based on reference tables published by Metropolitan Life Association (78). Biertho et al, suggested that GBS yielded a higher EWL at 18 months when compared to GB (79). In a recent meta-analysis, mean EWL after GB was 47.5% (range = 40.7 to 54.2%), GBS was 61.6% (range = 56.7 to 66.5%) and BPD 70.1% (range = 66.3 to 75.9%) (16).

2.2.2 Complication of bariatric surgery

The mortality rate associated with bariatric surgery has been reduced significantly over time with deaths generally occurring in less than 1% of patients. This decrease has been noted as a result of the use of laparoscopic procedures in recent years and improved standards for hospitals and surgeons performing bariatric surgery (80). The most common causes of death from bariatric surgery are pulmonary embolism (30%), intra-abdominal leaks (14%) and myocardial infarction (12%) (81;82).

Bariatric surgery may also result in adverse effects resulting from vitamin and mineral deficiencies (83). Due to alterations of the digestive tract with procedures such as BPD, it is a challenge to maintain recommended levels of some nutrients including protein, vitamins and minerals, and this procedure is particularly associated with deficiencies in fat soluble vitamins, iron and calcium. With GBS there is the potential for reduced absorption of calcium, iron, and the B-complex vitamins. GBS and BPD may also result in "*dumping syndrome*", which occurs with the rapid emptying of sugars or carbohydrates from the gastric pouch into the small intestine. Dumping syndrome causes a release of hormones that affect the autonomic nervous system resulting in an increased heart rate, a flushing sensation, and this is often accompanied by diarrhea. Gastric-restrictive operations such as GB have reported iron deficiency but this is usually in menstruating women or due to reduced meat intake (83). The most common nutritional complications after bariatric procedures are illustrated in a chart below (Table 1).

Table 1: Common nutritional complications after bariatric surgery

Nutritional Complications	**GB**	**GBS**	**BPD**
	Nausea &vomiting	Nausea & vomiting	Nausea & vomiting
		Dumping Syndrome	Dumping Syndrome
		Iron deficiency Calcium Malabsorption B_{12} deficiency	Iron deficiency Calcium Malabsorption B_{12} deficiency Fat-soluble vitamin deficiencies Protein calorie malnutrition

2.2.3 Benefits of bariatric surgery

2.2.3.1 Reduction in mortality

Recent studies have suggested that the effect of bariatric surgery on health related outcomes may contribute to a reduction in mortality in obese adults (84;85). Sjostrom et al. conducted a prospective, controlled study of bariatric surgery in which obese patients desiring bariatric surgery were matched to patients not desiring bariatric surgery (19). Two thousand and ten subjects (surgical group) underwent a bariatric surgical procedure that included vertical banding gastroplasty (68% of subjects), gastric banding (19% of subjects), or gastric bypass (13% of subjects), with these subjects compared to 2037 non-surgical subjects who received a minimally intensive weight loss treatment. Following 10 years, weight loss ranged from 14 to

25% of initial weight in the surgery group compared to an average of 2% of initial body weight in the minimally intensive weight loss treatment group. Moreover, there was a 29% reduction in the adjusted hazard ratio for death at the 10 year follow-up in the bariatric surgery group (19). In a retrospective cohort study, Adams et al. showed that GBS was associated with 40% lower adjusted mortality rates (86).

2.2.3.2 Reduced morbidity

Bariatric surgically induced weight loss may be an effective treatment for many conditions such as type 2 diabetes, hypertension, and high cholesterol. Results from the Swedish Obesity Subjects study (SOS Study) demonstrated a reduction in the incidence of type 2 diabetes from 24% to 7% and hypertriglyceridemia was reduced from 27% to 17% 10 years post weight loss surgery. The beneficial effects of weight loss surgery on blood pressure was also shown at the 2 years follow-up (87). However, at 10 years post surgery the blood pressure levels were not influenced by the weight reduction induced by bariatric surgery (88). Recently in a randomized trial, Dixon et al. reported that at 2 years post-adjustable gastric banding surgery, the participants assigned to the surgical group for weight loss (73% of the patients) had a 5 times higher remission rate of type 2 diabetes, as defined as achieving a fasting glucose level , 126 mg/dl and glycated hemoglobin value 6.2% while taking no glycemic therapy in contrast to those who received standard conventional approaches to weight loss and diabetes control (13% of the patients) (89). In a comprehensive review, by Buchwald et al, the authors summarized data and reported that bariatric surgery (including gastric bypass and gastric banding) resolve or improve in a large percentage of patients after bariatric surgery (90).

There are also reports of reduced musculoskeletal pain resulting from bariatric surgically induced weight loss. Peltonen et al. reported an improvement in recovery rate for pain in the knee and ankle for men and pain in the cervical spine, low back, hip, knee, and ankle for women

2 years after bariatric surgery compared to a control group (non-surgical treatment group) who were porting pre-existing pain based in self administered questionnaires (91). Hooper et al. also found a significant improvement in musculoskeletal symptoms after weight loss induced by GBS; with the greatest improvements noted in the spine (cervical and lumbar) and the foot in individuals previously reporting pain (50). Melissas et al. reported a reduction in functional disability resulting from low back pain following bariatric surgery (92). Results from the SOS Study also showed improved HRQOL (total score) following bariatric surgery, with the improvement in HRQOL shown to be associated with the magnitude of weight loss (67).

2.2.4 Long-term impact of bariatric surgery

Despite the fact that most people lose a significant amount of weight after surgery, emerging data from long term follow up (after 24 months) is suggesting that many patients regain weight and have a relapse of co-morbidities (16;24;28-30). Christou et al. reported significant weight regain in patients who had a Roux-en-Y gastric bypass from an EWL of 89% at 2.5 years post-surgery to an EWL of 68.1% by 12 years post-surgery (93). The results of the SOS study also demonstrated that patients had successive weight regain mainly between 1 and 6 years after surgical intervention. The reported maximum weight loss in the surgical group was 25% at 1 year follow-up and thereafter, there was gradual weight regain observed resulting in a weight loss of 16.9% at 6 years, meaning that about 30% of the initial weight reduction was regained within 5 years. Weight regain stabilized between the 6 and 10 year post-surgical follow-up resulting in approximately 16% surgical weight loss at 10 years (67).

Little is known about the potential causes of fluctuations in body weight long-term following bariatric surgery. One mechanism to explain fluctuations in body weight post–surgery may be a reduction in energy requirements. Das et al examined changes in energy expenditure in individuals who have undergone weight loss surgery, and reported that energy requirements and resting energy expenditure (REE) are significantly reduced after weight loss surgery. The reduction in REE was explained by both the loss of fat free mass (FFM) and fat mass; however, there was no significant long-term change in energy efficiency that would independently promote post-surgical weight regain (94).

There is a paucity of studies examining other potential explanations such as behavioral factors that may lead to the variability of weight loss observed in individuals who have undergone bariatric surgery (94). Most research has focused on examining eating behaviors after surgery (such as dietary adherence and eating disorders) (31-35) but there has been relatively little investigation of physical activity behavior of bariatric surgery patients and how factors of physical activity contribute to long-term surgical outcomes (20;29). Although physical activity participation is considered a crucial factor for surgical success and is a standard recommendation postoperatively, there are no comparative studies on the impact of this on long term surgical outcomes (20;29).

In 2003, the Longitudinal Assessment of Bariatric Surgery (LABS) clinical research consortium was established with the intent of conducting studies that would ultimately provide a greater understanding of the impact of bariatric surgery on various outcomes. The goal of the LABS consortium is to provide information on patient characteristics, medical and psychosocial outcomes and other factors that will guide the development of evidence based recommendations for post-surgical care (95). However, despite the development of this consortium, questions remain with respect to the impact of physical activity on long-term weight loss success following bariatric surgery (39). Specifically questions that remain include the activity patterns of patients following bariatric surgery and the influence of physical activity on weight loss and related health outcomes following bariatric surgery. This dissertation study examined these important questions related to bariatric surgery.

2.3 IMPORTANCE OF PHYSICAL ACTIVITY

Regular exercise and habitual physical activity have been shown to be a determinant of long term management of body weight in obese individuals (36;96-99). Evidence exists to support physical activity as an important component of weight maintenance after weight loss in sedentary, obese adults; however, there are few studies that examine physical activity patterns in obese individuals post-surgery (100). Moreover, despite reports that physical activity levels increase 6 months after bariatric surgery (101), there is little known about long-term changes in energy expenditure post-bariatric surgery, and there is limited information regarding exercise adoption and adherence in this population. This information may be important for establishing long term recommendations and clinical guidelines related to physical activity for post-bariatric surgery patients.

2.3.1 Physical activity and weight loss maintenance within behavioral interventions

Exercise and physical activity have been shown to play a critical role in energy balance, weight control, disease prevention, and achievement and maintenance of overall health. A minimum of 150 minutes/week of moderate intensity exercise are endorsed by both The Office of the US Surgeon General, Center for Disease Control and Prevention and the American College of Sports Medicine (ACSM) (38, 99). However, there is increasing evidence that a higher level of physical activity may be necessary for weight loss maintenance in post obese individuals after undergoing a dietary intervention. The recent public health recommendations have specified that 60-90 minutes of moderate activity is needed to prevent weight re-gain (36).

Long term follow up data from several trials suggest that physical activity plays an essential role in weight loss maintenance (36;96-98). Several studies have shown a strong correlation between the amount of physical activity and weight loss maintenance after a dietary intervention (98). Using the gold standard doubly labeled water method to obtain activity levels, Schoellar et al, reported that 77-80 minutes of daily activity added to a sedentary lifestyle was needed to prevent weight regain in the year after weight loss (102). In a randomized controlled trial, Fogelholm et al examined the effects of a walking program on weight maintenance after a diet. The results showed that a moderate intensity walking maintenance program had a significant impact on weight maintenance (103). Rissanen et al also demonstrated an association between the amount of physical activity and weight loss maintenance after a dietary intervention. The researchers performed an observational study on a large population of subjects for over 5 years after weight loss. The results showed that a physical activity level of $\geq$ 300 minutes a week was needed for weight maintenance after a diet (104). In addition, data from the National Weight Control Registry (NWCR) support the idea that high levels of physical activity are critical to weight loss success. The NWCR is a registry of over 6000 individuals who have maintained a minimum of 13.6 kg weight loss for at least a year. Ninety percent of the members of NWCR report exercising regularly resulting in an average energy expenditure of 2682 kcal per week (105).

Several studies have shown a clear dose response relationship between physical activity and weight maintenance. For example, Jakicic et al showed that greater levels of physical activity were associated with improved weight loss maintenance in overweight and obese females. In a retrospective analysis, the group of women who exercised >200 minutes lost significantly more weight than the group who exercised <150 minutes per week at one year. Additionally, women averaging approximately 280 minutes of exercise per week showed no weight regain from 6 months to 18 months follow up (106). Jeffery et al further provides support for an association between the amounts of physical activity performed and long term weight loss maintenance. Overweight subjects were randomly assigned to standard behavioral therapy (energy expenditure of 1000 kcal per week) or to a high level of physical activity group (energy expenditure of 2500 kcal per week). At six months there was no significant difference in weight loss between groups. Weight loss, however was significantly greater in the high level of physical activity group at both 12 months (-8.5±7.9 kg versus -6.1±8.8 kg) and 18 months (-6.7±8.1 kg versus -4.1±8.3 kg) (107).

2.3.2 Physical activity for weight loss maintenance post- bariatric surgery

Despite the growing body of scientific evidence to support the need for sufficient levels of physical activity to improve long term weight loss maintenance after a behavioral intervention, empirical evidence is lacking regarding the need for physical activity specific to weight loss and weight maintenance among individuals who have undergone bariatric surgery.

Recent preliminary studies have shown that physical activity plays a role in successful weight loss and maintenance after bariatric weight loss surgery, specifically GBS (39;40;108). Bond et al examined physical activity participation in 1585 patients who underwent GBS (40). Physical activity was assessed using a self report that did not quantify the level of physical activity or amount of energy expenditure, only if they participated in physical activity. The findings in this study showed that patients who reported physical activity participation as defined by a questionnaire were younger, had greater %EWL, and a greater decrease in BMI at 2 years post surgery. Boan et al (101) examined changes in physical activity level after GBS, with subjects assessed at baseline (pre-op) and at 6 months post-operatively. The results showed a significant improvement in the subjects' level of reported activity, energy expended in physical activity participation (from 239.8 kcal/wk to 1230 kcal/wk), and a decrease in reported amount of time watching TV following GBS. Klem et al. compared self-reported physical activity levels in 67 subjects who received bariatric surgery and 67 subjects who lost weight through non-surgical means using the Paffenbarger Activity Questionnaire. The subjects were selected from the NWCR and were matched for gender, current weight status, and total weight loss. Both groups reported being very physically active but interestingly, the non-surgical subjects reported current activity levels nearly twice as high as those reported by the surgical group (2984.9 kcal/week versus 1504.2 kcal/week) (109).

Despite the findings, there are limitations to these studies that should be addressed. One of which is the methodology used to assess physical activity. In all of these studies the investigators relied on self-reported rather than objectively measured physical activity. It has been shown that an inherent limitation of self-reported measures of physical activity is the validity of these measures; as it has been shown that subjects tend to over report energy expenditure in physical activity (110). Therefore, there is a need for studies examining physical activity in patients undergoing bariatric surgery to include objective measures of physical activity to confirm the findings from these previous studies. This study included objective measures of physical activity (by using an armband activity monitor that collects and analyzes physiological and lifestyle data to determine energy expenditure) in an attempt to overcome the measurement limitations of previous studies of physical activity in bariatric surgery patients.

2.3.3 Exercise adherence and weight control

Research has shown that physical activity has a positive effect on weight maintenance among those who adhere to the recommendations of the program. However, such increases in physical activity are often not maintained over long time periods as decay of adherence to the exercise programs has been reported to be as high as 50% within 6 months of initiating the exercise regimen (111). Weight loss studies that have included physical activity as a treatment intervention have shown that increased physical activity is a strong contributor to maintaining weight loss and the lack of adherence to physical activity recommendations was associated with weight regain. Jakicic et al reported a decline in exercise participation after 6 months of a behavioral intervention of diet and exercise and noted that the decrease in participation of exercise resulted in 15-30% weight regain in obese women (106).

Ekkekakis et al reported that lower levels of adherence to exercise programs specifically walking programs are commonly found among obese adults compared to adults that are of normal weight (112). This, in part, can be due to the reported displeasure with walking. Obese subjects reported higher exertion levels, increased body temperature, and increased musculoskeletal discomfort to the walking activity when compared to normal weight individuals which may have influenced reported displeasure in the obese subjects (112).

2.3.4 Psychosocial factors affecting physical activity participation

Many factors influence physical activity participation and induce long term behavioral change. Demographic variables such as age, gender, and educational levels seem to be the strongest determinants of physical activity behaviors and participation. Several studies have shown that physical activity participation is higher in men and inversely associated with age and lower educational level (44;113;114). For obese adults, participation in an exercise program has been associated with intrapersonal variables such as physical activity self-efficacy, perceived barriers to physical activity and social support (41;44;115;116).

Physical activity self-efficacy as defined by Bandura as the confidence that one can engage in physical activity across different challenging situations such as fatigue or inclement weather (117) and has emerged as the most consistent correlate of physical activity behavior. Sternfeld et al. reported that women who had high levels of physical activity self-efficacy were significantly more likely to engage in a higher level of physical activity then those with low levels of self-efficacy (116). Omen et al examined the influence of physical activity self- efficacy among healthy sedentary adults who participated in a supervised home based exercise program. Among these subjects, baseline self-efficacy perceptions significantly predicted exercise adherence at a 2 year follow-up (118).

Numerous barriers and obstacles to physical activity have also emerged as strong predictors of activity participation. These range from personal barriers such as lack of time and motivation, to environmental barriers such as unsafe neighborhoods (119;120). Gallagher et al. studied the effects of a 6 month behavioral intervention on psychosocial variables of physical activity and stated that participants who reported higher levels of physical activity and $\geq$ 10% weight loss also reported higher levels of physical activity self-efficacy, greater use of behavioral strategies to elicit social support, and fewer barriers to physical activity (45).

Despite the breadth of knowledge related to correlates of physical activity, there is very limited information available related to correlates of physical activity in patients undergoing bariatric surgery. Bond et al assessed the relation between stage of physical activity readiness and physical activity level in GBS candidates. This study showed that 100% of subjects who were surgical candidates reported an intention to engage in physical activity (121). However, the influence of psychosocial factors (i.e. perceived barriers to exercise, expectations and benefits of exercise, and self-efficacy for physical activity) on physical activity participation have not yet been studied in individuals who have undergone bariatric surgery. This study examined the potential psychosocial correlates of physical activity in subjects 2-5 years post-bariatric surgery. Defining the correlates of physical activity participation in this group may provide a better understanding of physical activity behavior following bariatric surgery, which may influence the design of effective intervention for weight management that is tailored to the individuals after bariatric surgery.

2.4 PILOT STUDY. THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY, PHYSICAL PERFORMANCE AND PSYCHOSOCIAL VARIABLES IN INDIVIDUALS S/P GASTRIC BYPASS SURGERY

An initial pilot study was conducted to gain a better understanding of the relationship between physical activity behaviors and attitudes to physical activity participation in patients' pre-operatively and 3 months post gastric bypass surgery (GBS). This study proposed to define a behavioral profile of participants, pre and post GBS by characterizing their level of physical activity and attitudes associated with physical activity participation. Twenty (18 female and 2 male) candidates for GBS (mean age 43) were asked to complete the 7 day physical activity recall self-report (7-day PAR), a 7 day pedometer diary, the SF-36 to assess HRQOL, physical activity self-efficacy (PASE), expected outcomes and barriers to physical activity, and the numeric pain rating scale (NPRS) self-report questionnaires. In addition, subjects' performance on the 6 minute walk test (6MWT) and the Short Physical Performance Battery (SPPB) were evaluated. This study was approved by the Institutional Review Board at the University of Pittsburgh.

At 3 months the subjects in this pilot study showed a trend towards increased levels of physical activity and physical function, along with a significant reduction in low back and joint pain and significant improvement in HRQOL. These findings are illustrated in Figures 2, 3, and 4. There was a significant association between level of physical activity and physical performance outcome (6MWT and SPPB), but level of physical activity was not related to any other outcome variables. This study was built on these preliminary findings to better understand physical activity patterns in adults at 2-5 years post weight loss surgery.

Figure 2: Self-reported level of physical activity

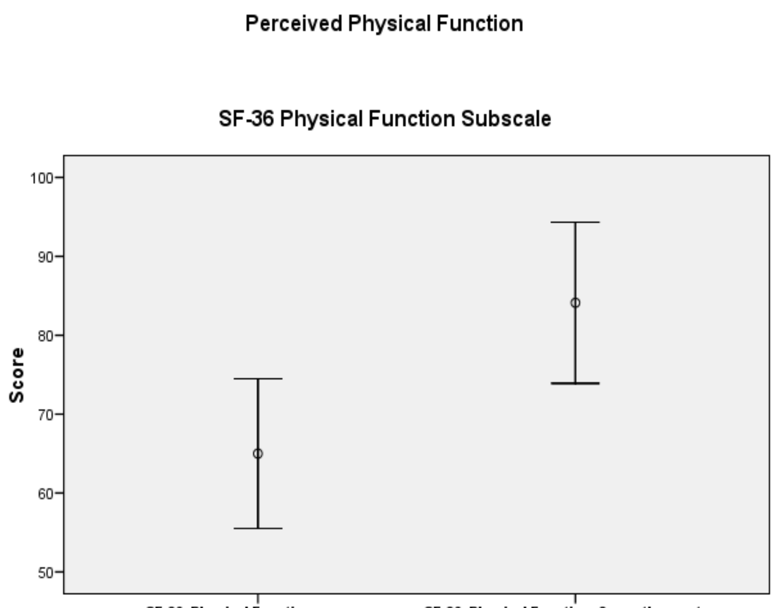

Figure 3: Self reported perceived physical function

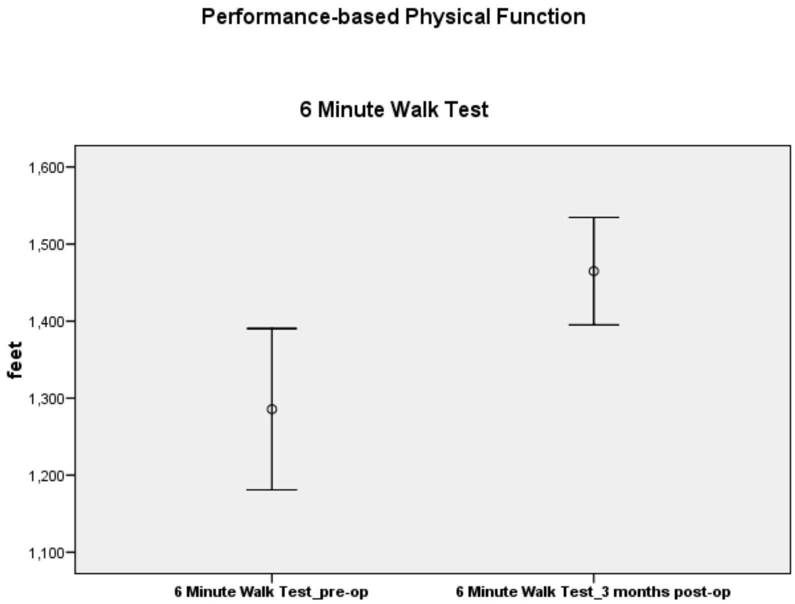

Figure 4: Performance-based physical function

2.5 CONCLUSION

The number of individuals who are morbidly obese (BMI $\geq$40 kg•m^{-2}) is increasing at a rapid rate and the treatment of this condition continues to be a major challenge. Currently the most viable option for weight loss for these individuals is bariatric surgery. Success following surgical procedures is guided by the individual's ability to make lifestyle changes. Though dietary restrictions are stressed in conjunction with weight loss surgeries, few studies have investigated the effect of physical activity on maintenance of long term weight loss after these surgeries. Examining the relationship between weight loss and physical activity may be a key factor impacting the long term success for these patients after bariatric surgery. Consequently, a better understanding of the characteristic profile of individuals who have undergone bariatric surgery may contribute to the development of effective post-surgical exercise guidelines and could lead to improved weight loss and surgical success.

The purpose of this study was to expand on the aforementioned work by examining the degree of participation in physical activity by individuals who are 2-5 years s/p bariatric surgery. The effects of psychosocial factors such as physical activity self-efficacy, perceived barriers to exercise, outcome expectations, and HRQOL were also examined as they may contribute to the variability of physical activity behavior in these individuals. This knowledge of the physical activity behavior and examining attitudes toward physical activity in this population will assist in the development of effective post-surgical exercise guidelines. The results of the study are an important prerequisite to designing an effective exercise intervention for this population that can be tested in a randomized clinical trial.

3.0 METHODS

3.1 REASEARCH DESIGN

This study used a cross sectional design to examine the specific aims stated in Chapter 1. Specifically, this study recruited subjects who had undergone a bariatric surgical procedure between 2 and 5 years ago to examine if physical activity is related to %EWL and factors related to physical activity participation. A description of the inclusion/exclusion criteria, recruitment strategies, screening procedures, and assessment procedures are provided in detail below.

3.2 SUBJECTS

This study recruited 37 adults (female and male) who have undergone bariatric surgery for weight reduction between 2-5 years ago. It was expected that gastric bypass (GBS) would be the predominant procedure observed in this study (17); however, subjects undergoing other forms of bariatric surgical procedures performed for the purpose of weight loss were also eligible for participation in this study.

Individuals were considered eligible if they meet all of the following criteria:

1. $\geq$18 years of age.

2. Able to provide verification that he/she had undergone a form of bariatric surgery between 2-5 years ago. Bariatric surgical procedures may include gastric bypass, gastric banding, vertical banded gastroplasty, sleeve gastrectomy, etc.
3. Able to provide written informed consent.
4. Able to complete all assessment procedures.

Individuals were excluded from this study if they meet the following criteria:

1. Are s/p bariatric surgery revision.
2. Have been pregnant within the prior 6 months. This exclusionary criterion is being used to minimize the effect of post-partum weight fluctuations on the outcomes of this study.
3. Are unable to independently walk at least 150 feet. This exclusionary criterion is being used because the primary outcome of this study is physical activity, and therefore it is important that the individuals are mobile. The ability to walk 150 feet independently was based on the Barthel Index, a valid measure of physical disability, which uses this distance as a measure of mobility (122).
4. Are unable to wear the BodyMedia SenseWear® Pro armband on the upper right arm for 7 consecutive days.

3.3 RECRUITMENT PROCEDURES

Subjects were recruited from three possible sources that included: 1) physician referral from the Minimally Invasive Surgery Center at the Magee-Womens Hospital of the University of Pittsburgh Medical Center (UPMC), 2) an NIH funded study (DK078562-01) *"Behavioral Intervention for Failure After Bariatric Surgery: Optimizing Long-term Weight Control"*

(Principal Investigator: Melissa Kalarchian, Ph.D.) and 3) from community advertisements in local newspapers, flyers, and other forms of media. These are described in greater detail below, and all recruitment procedures were approved by the University of Pittsburgh Institutional Review Board (IRB).

1) Recruitment from physician referral within the Minimally Invasive Surgery Center at the Magee-Womens Hospital of UPMC

Subjects were recruited from an existing clinic in which bariatric surgery procedures are performed. A health care worker associated with this clinic (i.e. nurse, etc.) identified individuals who meet the 2-5 year post-surgical criteria for participation in this study when they came to the clinic for their post-surgical follow-up visit. The health care worker informed the subjects of the study during their follow-up visit. A written script was provided for the healthcare worker to read to the patient describing the study. If the patient was interested, a telephone number was provided to the patient to contact the investigators for further information and further eligibility screening. In the event that the researcher was present in the clinic during the patient visit, the researcher met with the patient during this visit to conduct this additional eligibility screening.

2) Recruitment from ongoing NIH-funded Study (Principal Investigator: Melissa Kalarchian, Ph.D.)

Subjects were recruited from an ongoing NIH-funded study that is examining outcomes related to bariatric surgery. Subjects were identified as potentially eligible for this study by the project coordinator. A written script that described the study was provided for the project coordinator to read to the participant. If the participant was interested, a telephone number was provided to the individual to contact the investigators for further information and additional eligibility screening. In the event that the researcher was present in the research center at the time of the participant's visit, the researcher met with the participant during this visit to conduct this additional eligibility screening.

3) Community advertisements

Participants were also recruited using various forms of media (i.e. newspaper, flyers, television, radio, etc.). These advertisements were approved by the University of Pittsburgh Institutional Review Board. Individuals interested in participating in this study were provided a telephone number to call. In response to this call the investigator provided a brief description of the study via telephone and conducted an initial study eligibility screening during this call.

As part of the screening procedures, individuals were required to provide documentation that they had undergone a bariatric surgical procedure between 2 and 5 years prior to participation in this study. For subjects recruited through the Minimally Invasive Surgery Center at the Magee-Womens Hospital of UPMC, the investigator obtained permission from the participant to review their medical chart to confirm the type, pre-surgical weight and date of their surgery. For subjects recruited through Dr. Kalarchian's study, subjects provided permission for the investigator to use the verification of surgery obtained for that study to confirm the date, pre-surgical weight and type of surgery for this study. For subjects recruited through community media efforts, the investigator obtained permission from the individual to contact their surgeon to obtain information regarding the date, pre-surgical weight and type of bariatric surgical procedure.

3.4 ASSESSMENT PROCEDURES

Individuals who were eligible based on the initial screening procedures underwent a series of assessments for this study. To allow for convenience for the participants, these assessments were conducted at one of the following locations:

1) The Minimally Invasive Surgery Center at the Magee-Womens Hospital of UPMC
2) The Iroquois Building, Suite 606
3) Physical Activity and Weight Management Research Center, University of Pittsburgh, Birmingham Towers
4) Forbes Tower, Room 5052, University of Pittsburgh
5) UPMC Outpatient CRS Clinics

All subjects underwent assessments of body weight, height, body mass index (BMI), physical activity, questionnaires to assess psychosocial factors and perceived physical function, and questionnaires to obtain a detailed medical history, demographics and dietary intake. The assessment timeline is illustrated in Table 2. Procedures for this study were approved by the Institutional Review Board at the University of Pittsburgh and written consent was obtained by all participants. Assessments are described in detail below.

Table 2: Study Timeline

	Procedures Performed
Recruitment	• Individual expresses interest in study
Initial Screening	• Investigator conducts initial screening of interested participant by telephone or in-person. • Date, pre surgical weight and type of surgical procedure verified.
In-clinic Assessment	• Sign inform consent • Demographic questionnaire completed • Medical History questionnaire completed • 2005 Block Food Frequency questionnaire completed • Measurement of Height and Weight • Psychosocial questionnaires completed • Physical activity - Armband fitted to subject - Subject provided instructions on wearing the armband - Subject provided a physical activity diary - Subject provided a postage paid return envelope
1 Day Post Assessment	• Physical activity - Subject wears that armband to assess physical activity - Subject completes the physical activity diary • The investigator contacts the participant to determine if there was any difficulty with wearing the armband and to answer any questions related to wearing of the armband.
2 Days Post Assessment	• Physical activity - Subject wears that armband to assess physical activity - Subject completes the physical activity diary
3 Days Post Assessment	• Physical activity - Subject wears that armband to assess physical activity Subject completes the physical activity diary
4 Days Post Assessment	• Physical activity - Subject wears that armband to assess physical activity - Subject completes the physical activity diary • The investigator contacts the participant to determine if there was any difficulty with wearing the armband and to answer any questions related to wearing of the armband.
5 Days Post Assessment	• Physical activity - Subject wears that armband to assess physical activity - Subject completes the physical activity diary
6 Days Post Assessment	• Physical activity - Subject wears that armband to assess physical activity - Subject completes the physical activity diary
7 Days Post Assessment	• Physical activity - Subject wears that armband to assess physical activity - Subject completes the physical activity diary
8 Days Post Assessment	The investigator contacts the participant to remind him/her to return the armband in the postage paid envelope that was provided to them.

3.4.1 Demographics questionnaire

Subjects completed a questionnaire to document age, gender, education, employment, ethnicity, and marital status. Activity recommendations provided by the surgeon or health care providers post surgery were also documented.

3.4.2 Medical history questionnaire

A general health history was completed by the subjects. This questionnaire entailed questions regarding medical history, medications and complications, if any, associated with the surgical procedure. Example of complications related to the surgery could be nausea and vomiting, dumping syndrome, stomal stenosis, esophageal dilation, band slippage, anastomic ulcer, incisional hernia, and a gastro-gastric fistula.

3.4.3 Dietary intake

To analyze dietary intake as a descriptive variable subjects completed the 2005 Block Food Frequency Questionnaire. This full-length (approximately 110 food item) questionnaire was designed to estimate usual and customary intake of a wide array of nutrients and food groups.

3.4.4 Body weight, height, and BMI

Body weight was assessed using a calibrated scale. Subjects were in their clothes and shoes were removed for this assessment. Height was assessed using a calibrated stadiometer and subjects removed their shoes for this assessment. Body weight was expressed as absolute body weight and expressed as percent of excess body weight lost (%EWL). Excess weight is the weight of a person minus the person's ideal body weight, with the ideal body weight based on reference tables published by Metropolitan Life Association (78) (%EWL: [(initial wt - follow up wt) / (initial wt - ideal wt)] x 100). BMI was computed from measurements of weight and height (kg/m^2).

3.4.5 Physical activity

Physical activity was assessed using the BodyMedia SenseWear® Pro armband activity monitor. The BodyMedia SenseWear® Pro armband has been shown to provide an accurate assessment of free living energy expenditure (123). The BodyMedia SenseWear® Pro armband is a wireless, wearable body monitor that collects and analyzes physiological and lifestyle data to determine energy expenditure, activity levels and sleep/wake states. It is a small (weighing less than 3 ounces) self contained device that is worn continuously on the back of the right upper arm (Triceps). The monitor collects four types of data: temperature of the skin, galvanic skin response, heat flux, and a measure of motion via an accelerometer which are translated by algorithms into descriptors of energy expenditure such as duration of activity, number of steps a person takes daily, and the time spent lying down and sleeping. The BodyMedia SenseWear® Pro armband provides no feedback to the subject and thus, does not encourage "performance behavior" (123;124). The proprietary algorithms within Version 6.1 of the SenseWear® Professional Software were used to compute energy expenditure per minute. For this study, physical activity was defined as the total minutes per day of moderate to vigorous activity, with moderate to vigorous activity defined as activity that is $\geq$3METs.

The subjects were given the BodyMedia SenseWear® Pro armband on the day of their assessment, and were shown how to wear the armband appropriately. Subjects were instructed to wear the BodyMedia SenseWear® Pro armband during all waking hours for 7 consecutive days following their assessment, and to only remove the armband when sleeping, bathing/showering or swimming. The subjects were also provided with an activity diary to record wearing time of the armband and times that they engage in activities that require removal of the armband. All subjects were provided with a postage paid padded envelope to return the BodyMedia SenseWear® Pro armband after the 7 consecutive days of the assessment period. The subjects were called by the investigator on the 1st day and 4th day after their assessment to ensure that the subject didn't encounter any difficulties with the armband and to remind them to wear the armband daily. The investigator also contacted the subject following the 7th day of wearing the armband to remind them to return the armband.

3.4.6 Perceived physical function

Perceived physical function was assessed using the physical function subscale of the Medical Outcomes Short Form-36 ($SF\text{-}36_{PF}$). The instrument, developed by Ware (125;126) is a well established, widely used, psychometrically sound health status questionnaire (127). This instrument measures limitations in 8 functional areas (physical activities, social functioning, physical factors, emotional factors, bodily pain, general mental health, vitality, and general health). The SF-36 has been proven to be a useful tool in assessing patient outcomes following bariatric surgery (128;128;129). The $SF\text{-}36_{PF}$ subscale assesses limitations in activities of daily living such as bathing, dressing and mobility limitations such as difficulty walking, climbing stairs and running.

3.4.7 Psychosocial correlates of physical activity

Self-Efficacy for Exercise: Self-efficacy is one of the central constructs in Social Cognitive Theory. Self-efficacy for exercise was assessed using the questionnaire by Marcus et al. The internal consistency of the 5 item self-efficacy measure is 0.76, and the test-retest reliability is 0.90 when assessed over a 2 week period (130).

Barriers and Expected Outcomes for Physical Activity: The questionnaire developed by Steinhardt and Dishman (131) was used to assess outcome expectations and barriers for physical activity. Internal consistency coefficients for this measure range from 0.47 to 0.78, with test-retest stability correlations ranging from 0.66 to 0.89.

Medical Outcomes Short Form-36 (SF-36) : The instrument, developed by Ware (125;126), is a well established, widely used, psychometrically sound health status questionnaire (127). This instrument measures limitations in 8 functional areas (physical activities, social functioning, physical factors, emotional factors, bodily pain, general mental health, vitality, and general health). The SF-36 has been proven to be a useful tool in assessing patient outcomes following bariatric surgery (128;128;129).

3.5 STATISTICAL CONSIDERATIONS AND POWER ANALYSIS

All analyses was performed using SPSS for Windows and statistical significance was defined at $p<0.05$. To examine Specific Aim #1, descriptive statistics (mean, standard deviation and range) were reported for subject characteristics and for all outcome measures. To examine Specific Aims #2, #3, #4 and #5 Pearson Correlation Coefficients were computed. Data was checked for normality, and if not normally distributed, the correlation coefficients were computed using the

Spearman Rank Order procedure. Also, where appropriate, we selected covariates to consider in the various analyses proposed. Selections of these covariates were based on statistical methodology through examining parameters that are statistically correlated with the variables of interest (i.e. weight and physical activity).

As indicated earlier in this study, it was expected that the majority of subjects would have undergone the GBS procedure. Therefore, the above mentioned correlation coefficients were computed only for those subjects who had undergone GBS to determine if the pattern of the results was affected when other forms of bariatric surgery were excluded from the analysis. If sample size permitted, the correlation coefficients would also be computed for each type of bariatric surgery performed.

It was also proposed that exploratory analyses be conducted based on the the level of physical activity achieved. Subjects were grouped into three groups based on physical activity level at the time of their assessment for this study. One-way analysis of variance was conducted to compare these groupings on measures of weight loss, perceived physical function and psychosocial outcomes as described above. Significant effects were further examined using post-hoc analysis with p-values adjusted using the Bonferroni procedure. Nonparametric test will be used for data that is not normally distributed.

Power Analysis: A power analysis was performed to determine an appropriate sample size for this proposed study. This power analysis was based on the primary analyses being correlation coefficients using a 2-tailed test. For this power analysis alpha was set at $p=0.05$ and statistical power set at 90%. Using these assumptions a sample of 45 subjects would be sufficient to detect a modest correlation of $r=0.45$ for the proposed specific aims of this study. However, to allow for the potential of a 10% attrition rate 50 subjects was proposed for this study. However, due to limitations in recruitment of subjects, the dissertation committee agreed to allow the doctoral candidate to proceed with 37 subjects for completion of the requirements for this dissertation.

4.0 RESULTS

The purpose of this study was to characterize the physical activity profile of individuals 2-5 years after bariatric surgery and examine the relationship between physical activity and percentage excess weight loss (%EWL). The relationship between level of physical activity, physical function and psychosocial factors associated with physical activity participation (self-efficacy, outcome expectations (benefits) & perceived barriers, and health related quality of life (HRQOL)) were also examined.

4.1 SUBJECTS CHARACTERISTICS

Table 3 provides a summary of the demographic variables for all subjects. Of the 37 subjects, 92% were female and the mean age was 50.76± 9.99 years. The mean BMI was 32.90±8.05 kg/m² and the mean % EWL was 62.15±19.93 with a range of 24.90-92.10%. Table 4 provides a summary of the co-morbid conditions within the sample. Over half (68%) of the subjects reported a history of high blood pressure, 51% reported anxiety/depression and 24% reported a history of osteoarthritis.

Laparoscopic gastric bypass was the only weight loss surgery represented in this sample. During the first year subjects reported post surgical complications but none reported an interference with participation in physical activity (Table 5). The recommendations for physical activity participation following the surgical procedure varied among the subjects. Forty three percent of the sample reported they received recommendations to exercise 3-5 days per week. However, 22% reported that they were not given any recommendation to engage in physical activity after surgery. Only 19% were given recommendations to exercise on most days of the week which is consistent with the current physical activity guidelines of 30 minutes a day on most days (99) (Table 6).

Table 3: Demographic Characteristics (n=37) (SD = Standard Deviation)

Characteristics	Mean	SD	Range	Number	%
Age (yrs)	50.76	9.99	32-66		
Weight (kg)	91.80	28.24	64.18-205.57		
BMI (kg/m²)	32.90	8.05	24.00-62.30		
EWL (%)	62.15	19.93	24.90-92.10		
Time post surgery (months)	43.65	12.85	24-60		
Gender					
Female				34	92
Male				3	8
Marital Status					
Married				21	57
Separated/Divorced				7	19
Widowed				1	3
Never Married				8	22
Education					
High School				9	24
Vocational Training				1	3
Some College				11	30
College/University				10	27
Graduate or Professional Education				6	16
Employment					
Not working				9	24
Professional				11	30
Clerical work, sales, technician				12	32
Crafts, trade, factory work service,				3	8
Other				2	5
Ethnicity/Race					
Black or African-American				4	11
Hispanic				1	3
White				32	87
Energy Intake (kcal/day)					
Percent Dietary fat Intake (%)	38.78	7.51	19.90-50.64		
Percent Carbohydrate Intake (%)	45.93	9.19	32.00-69.10		
Percent Protein Intake (%)	17.29	3.79	11.76-27.37		
Daily Caloric Intake (Kcal)	1292.4	457.7	468.7-2019.8		

Table 4: Frequency of co-morbidities (n=37)

Co-morbidity	n	% of total sample	Limits daily activity	
			n	% of total sample
Heart Disease	1	3	0	0
High Blood Pressure	25	68	0	0
Low Blood Pressure	3	8	0	0
Lung Disease	4	11	0	0
Diabetes	11	30	0	0
Ulcer or Stomach Disease	6	16	0	0
Liver Disease	1	3	0	0
Anemia or other Blood Disease	11	30	0	0
Cancer	5	14	0	0
Anxiety Disorder or Depression	19	51	4	11
Dizziness or Vertigo	6	16	1	3
Nerve Disease or Disorder	2	5	2	5
Thyroid Disorder	13	35	0	0
High Cholesterol	12	32	1	3
Osteoarthritis	9	24	3	8
Rheumatoid Arthritis	1	3	0	0
Neck or Back Injury	9	24	1	3
Allergies	14	38	1	3
Other	5	14	1	3

Table 5: Frequency of surgical complications (n=37)

Surgical complications	n	%
Nausea	21	57
Vomiting	20	54
B 12 Deficiency	13	35
Other Vitamin Deficiency	12	32
Diarrhea	12	32
Dumping	16	43
Gallbladder Disease/ Gallstones	8	22
Gastro-gastric Fistulae	1	3
Hernia	5	14

Table 6: Recall of physical activity recommendations (n=37)

Recommendations	n	%
No recommendations were given	8	22
Recommended to exercise with no guidelines	3	8
Recommended to exercise 1-2 days a month	2	5
Recommended to exercise 1-2 days a week	1	3
Recommended to exercise 3-5 days a week	16	43
Recommended to exercise most days a week	7	19

4.2 PHYSICAL ACTIVITY

Table 7 provides physical activity data for the subjects using a BodyMedia SenseWear® Pro armband. Of the 37 subjects in the sample, only 36 had complete armband data; one subject was not able to participate in this aspect of the study. The subjects spent an average of 205.33

±136.98 minutes per week engaged in moderate to vigorous intensity (≥3METs) physical activity. The majority of this time (77%) was spent engaged in sporadic bursts of activity (ranging from 1-9 minutes) and less than 23% of time (47.56 ± 69.84 minutes per week) was utilized for sustained activity bouts (10 or more continuous minutes). Subjects engaged in vigorous activity (≥6 METs) on a much less frequent basis, 5.72 ± 17.03 minutes per week at ≥ 1 minute bouts and 2.64 ± 12.49 minutes per week at ≥ 10 minute bouts (Figure 5).

Table 7: Descriptive data of physical activity when defined using different criteria (n=36)

Criteria to Define Physical Activity	Range	n	Mean ± SD
Total minutes/week @ $\geq$ 3 METs and $\geq$1-minute bouts	20-528	36	205.33 ±136.98
Total minutes/week @ $\geq$ 3 METs and $\geq$10-minute bouts	0-257	36	47.56 ±69.84
Total minutes/week @ $\geq$ 6 METs and $\geq$1-minute bouts	0-96	36	5.72 ±17.03
Total minutes/week @ $\geq$ 6 METs and $\geq$10-minute bouts	0-72	36	2.64 ±12.49

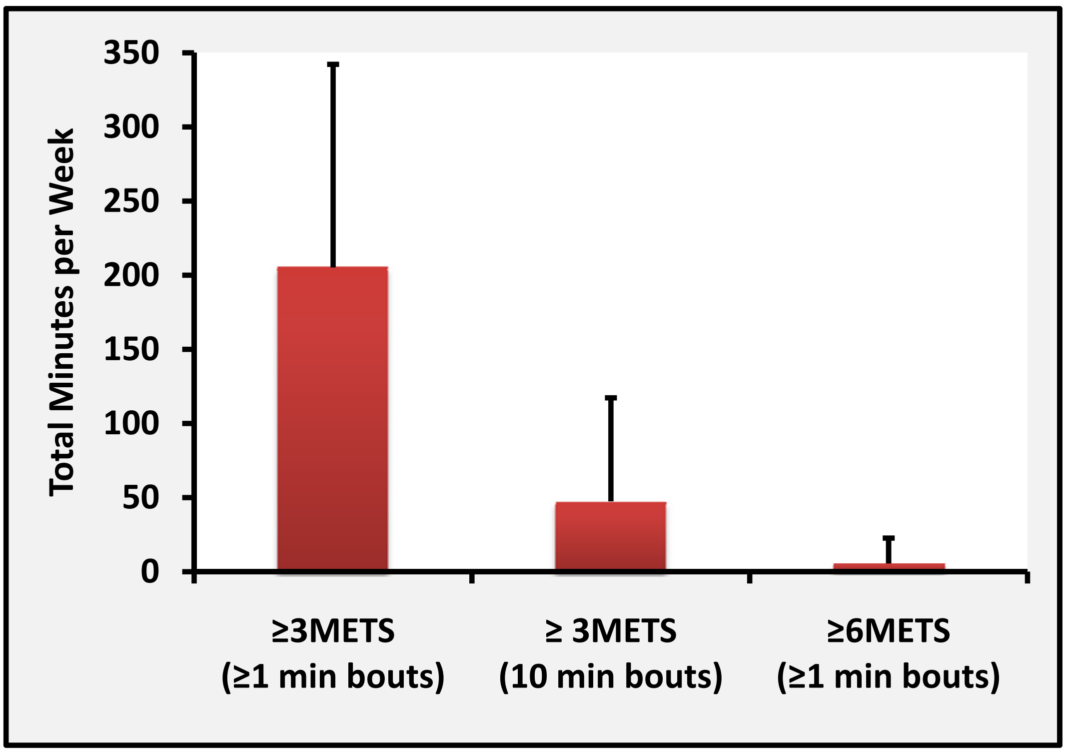

Figure 5: Total time spent at various intensities and durations (n=36)

The association between physical activity measures and %EWL were examined. Data were not normally distributed; therefore correlation coefficients were computed using the Spearman correlation procedure. A significant relationship between physical activity (total minutes per week engaged in moderate to vigorous activity (≥3METs) at ≥ 1 minute duration per bout) and %EWL was found (r=0.47, p <0.01) (Figure 6, Appendix E Figure 9). In addition, sustained physical activity (bouts of 10 or more continuous minutes of moderate to vigorous activity [≥3METs]) was significantly correlated with %EWL (r=0.35, p= 0.03) (Appendix E Figure 10). There was a significant relationship between physical activity (total minutes per week engaged in ≥ 3METs at ≥ 1 minute duration per bout) and absolute BMI (r= -0.39, p=0.02). Sustained physical activity (bouts of 10 or more continuous minutes of ≥ 3METs intensity) was significantly correlated with absolute BMI (r=-0.36, p=0.03). There was also a significant relationship found between physical activity (total minutes per week engaged in ≥ 3METs at ≥ 1 minute duration per bout) and % change of body weight (r=0.35, p=0.04). However, there was not a significant relationship between physical activity (bouts of 10 or more continuous minutes of ≥ 3METs intensity) and % change of body weight (r=0.25, p=0.14) As a group, those subjects who participated in greater levels of physical activity lost the most weight based on %EWL.

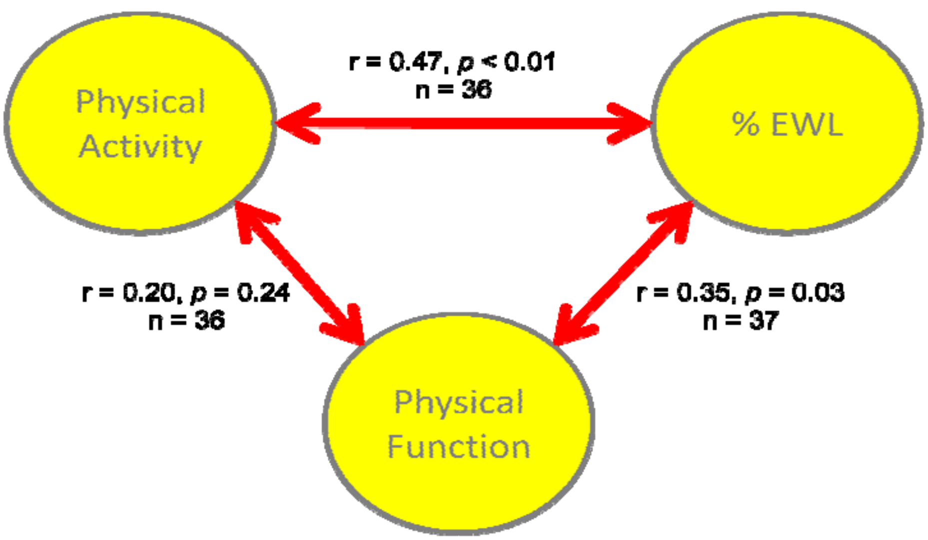

Figure 6: Relationship between physical activity, physical function and %EWL

Subjects were also grouped based on the total time spent engaged in moderate to vigorous physical activity. Subjects were placed into the following physical activity groups: (1) < 150 minutes per week (n=13), (2) 150-249 minutes per week (n=12) and (3) ≥250 minutes per week (n=11). Kruskal-Wallis ANOVA was conducted to compare these groups on the measure of weight loss. Analyses revealed an overall effect between the level of physical activity and %EWL (p= 0.049). Mann-Whitney analyses with p-value adjusted using the Bonferroni procedure revealed that %EWL was significantly greater (p=0.016) in the group who had 250 minutes per week or more of physical activity (68.78 ± 16.84) compared to the group with less than 150 minutes per week of physical activity (52.91 ±18.03). Percentage EWL in the group with 150-249 minutes per week (66.72 ±22.69) did not differ significantly from the other two groups (Figure 7).

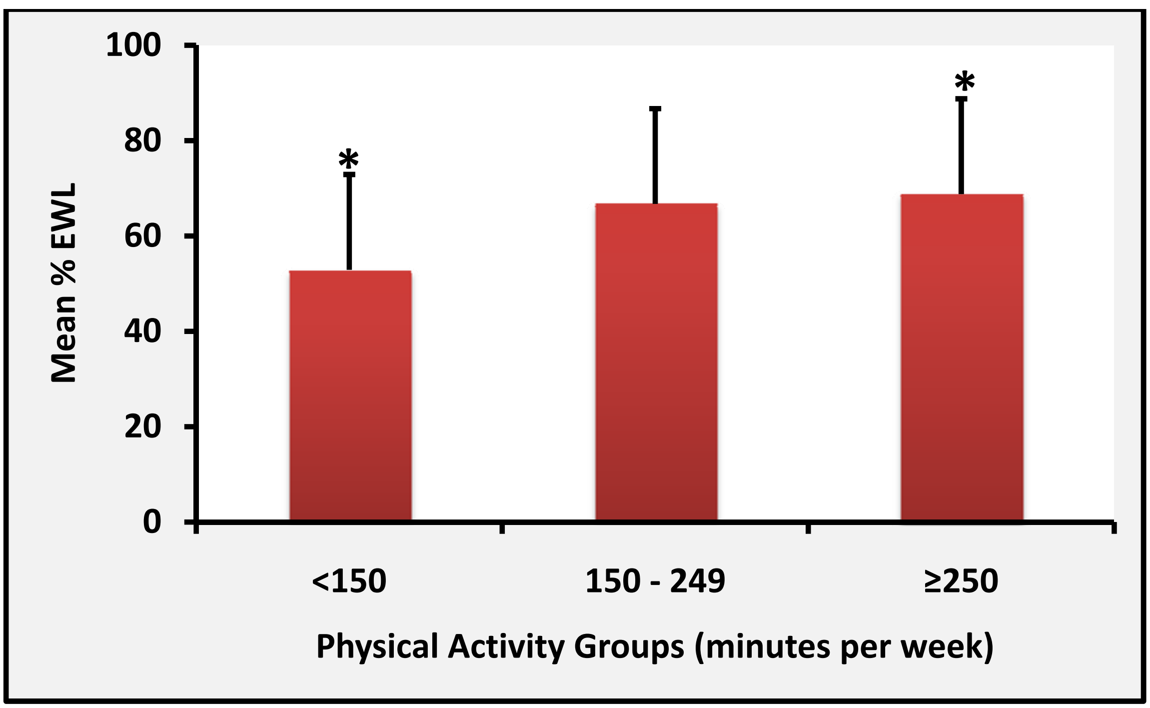

Figure 7: %EWL based on categories of physical activity participation (n=36) *denotes significant difference between groups (p< 0.05)

4.3 PHYSICAL FUNCTION

The mean score for the subjects' self reported physical function, using the SF-36 $_{PF}$ subscale, was 85.27 ± 23.94. Spearman rank order correlation coefficients were computed to determine the relationship between physical function and both physical activity and %EWL for the entire sample. No significant relationship was seen between level of physical activity and physical function (r=0.20, *p*=0.24) (Figure 6, Appendix F Figure 11). A significant relationship between %EWL and physical function was found (r=0.35, *p*=0.03) (Figure 6, Appendix G Figure 12). There was also a significant correlation found between absolute BMI and physical function (r=-0.40. *p*=0.02), however; there was not a significant correlation between %change of body weight and physical function (r=0.23, *p*=0.17).

ANOVA with Bonferroni-adjusted post hoc contrasts were conducted to examine differences in physical function between the three physical activity groups (<150 minutes per week, 150-249 minutes per week, ≥250 minutes per week). Due to the heterogeneity of variance in the physical function data a Kruskal-Wallis ANOVA was conducted. Analyses revealed no significant difference in physical function between the three physical activity groups (Figure 8 and Table 10).

Table 8: Descriptive data of psychosocial variables and health related quality of life (HRQOL) (n=37)

Variable	Mean ± SD
Psychosocial Variables	
Self-Efficacy:	
Tired	2.86 ±1.32
Bad Mood	3.22 ±1.32
Low on Time	2.68 ±1.18
On Vacation	3.38 ±1.26
Bad Weather	2.97 ±1.38
Total	3.02 ±1.13
Physical Activity Outcome Expectations:	
Psychological	3.58 ±0.80
Image	4.32 ±0.77
Health	4.60 ±0.59
Expected Outcomes (Benefits)	4.08 ±0.62
Physical Activity Perceived Barriers:	
Time	2.84 ±0.87
Effort	2.56 ±0.94
Obstacles	1.99 ±0.77
Perceived Barriers	2.45 ±0.60
HRQOL	
SF-36 Total Score	59.46 ±25.92

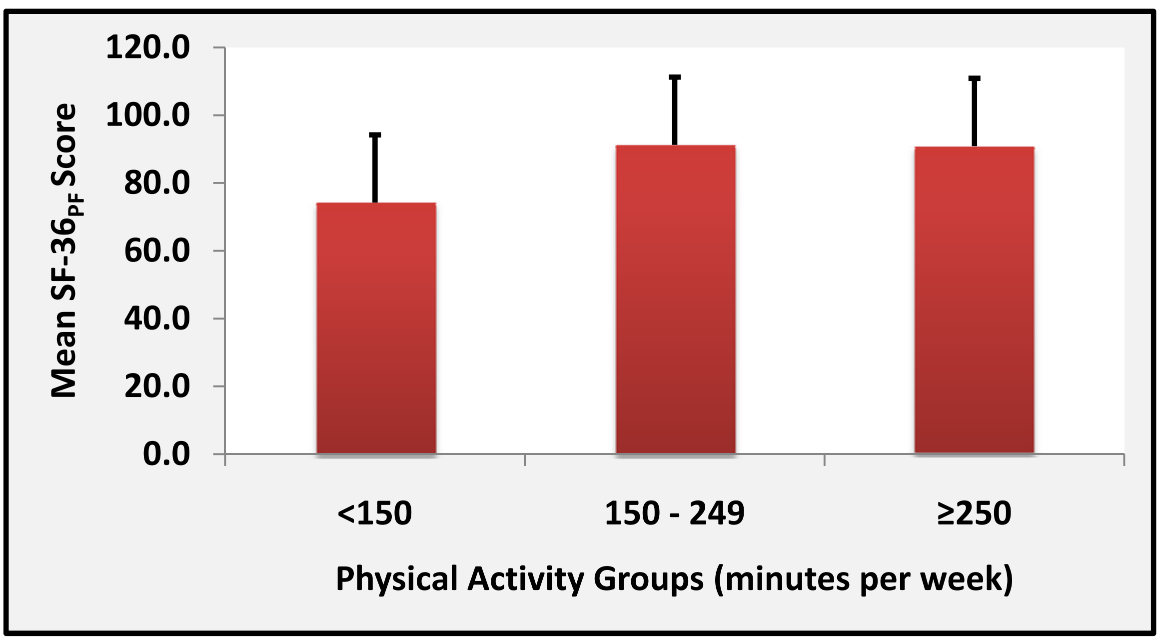

Figure 8: Physical function based on categories of physical activity participation (n=36)

4.4 PSYCHOSOCIAL VARIABLES

The means and standard deviations were calculated for psychosocial variables (physical activity self-efficacy, physical activity outcome expectations, physical activity perceived barriers, and HRQOL). Correlational analyses were performed to determine the relationship between physical activity (as defined as minutes per week that are ≥3METs and ≥ 1 minute bouts and minutes per week that are ≥3METs and ≥ 10 minute bouts) and psychosocial variables. Data were not normally distributed therefore correlation coefficients were computed using the Spearman correlation procedure.

Physical Activity Self-Efficacy

Data from the 5-item physical activity self-efficacy (PASE) questionnaire represents the subjects' propensity to exercise under the following conditions: when they are tired; in a bad mood; low on time; on vacation; and during bad weather. The mean score for the 5 items on the PASE was 3.02 ± 1.13. The subscale data for each of the PASE items are shown in Table 8. The correlations between physical activity and PASE are presented in Table 9. Self-efficacy for physical activity when tired (r=0.40, p=0.02), low on time (r=0.43, p=0.01), and the total PASE score (r=0.39, p=0.02) (Appendix H Figure 13) were significantly correlated with physical activity that was ≥3METs and ≥ 1 minute bouts. However, when examining the correlation between physical activity that was ≥3METs and ≥ 10 minute bouts and the subscales of the PASE, in a bad mood (r=0.34, p=0.045), low on time (r=0.45, p=0.01), in bad weather (r=0.35, p=0.04) and total score (r=0.40, p=0.02) (Appendix H Figure 14) were significantly correlated (Table 9).

Table 9: Correlations between physical activity and psychosocial variables (n=36)

Outcome Measures	Physical Activity			
	≥3METs & ≥1 min bouts		≥3METs & ≥10 min bouts	
	r	*p*-value	r	*p*-value
Self-Efficacy (PASE):				
Tired	0.40	0.02	0.28	0.09
Bad Mood	0.30	0.08	0.34	0.05
Low on Time	0.43	0.01	0.45	0.01
On Vacation	0.31	0.07	0.33	0.05
Bad Weather	0.30	0.08	0.35	0.04
Total	0.39	0.02	0.40	0.02
Physical Activity Outcome Expectations				
Psychological	0.33	0.05	0.34	0.04
Image	-0.07	0.67	-0.00	0.98
Health	0 .09	0.61	0.23	0.18
Expected Outcomes (Benefits)	0.24	0.16	0.30	0.08
Physical Activity Perceived Barriers				
Time	0.32	0.05	0.10	0.57
Effort	-0.25	0.14	-0.21	0.21
Obstacles	0.15	0.40	0.05	0.80
Perceived Barriers	-0.02	0.93	-0.07	0.68
HRQOL				
SF-36 Total Score	-0.02	0.90	0.01	0.96

Additionally, a Kruskal-Wallis ANOVA was conducted to examine physical activity self-efficacy between the three physical activity groupings (150 minutes per week, 150-249 minutes per week, and ≥250 minutes per week). No significant difference was observed in self-efficacy, between the 3 physical activity groups (Table 10).

Table 10: Comparison of variables between subjects grouped according to physical activity (min/wk)

Data reported as mean ±SD

Outcome Measures	**Low level activity**	**Moderate level activity**	**High level activity**	
	<150 min/wk (n=13)	**150-249 min/wk (n=12)**	**≥250 min/wk (n=11)**	***p***
Physical function	74.23 ±31.94	91.25 ±16.94	90.91 ±10.45	0.38
Self-efficacy (PASE $_{total}$)	2.75 ±1.31	3.00 ±1.07	3.42 ±0.97	0.31
Physical Activity Outcome Expectations:				
Psychological benefits	3.29 ±0.94	3.52 ±0.71	4.04 ±0.58	0.11
Image benefits	4.23 ±0.87	4.45 ±0.71	4.41 ±0.62	0.74
Health benefits	4.51 ±0.66	4.67 ±0.62	4.64 ±0.53	0.78
Benefits	3.91 ±0.70	4.12 ±0.61	4.31 ±0.48	0.25
Physical Activity Perceived Barriers:				
Time barrier	2.63 ±1.04	2.72 ±0.84	3.09 ± 0.54	0.15
Effort barrier	2.78 ±0.91	2.18 ±0.84	2.62 ±1.03	0.21
Obstacle barrier	1.88 ±0.86	1.92 ±0.69	2.25 ±0.77	0.35
Perceived barriers	2.47 ±0.65	2.22 ±0.59	2.62 ±0.53	0.34
HRQOL	65.38 ±26.10	54.17 ±25.75	59.09 ± 28.00	0.70

Physical Activity Outcome Expectations

Data from the physical activity outcome expectations included an overall total score and subscales: psychological, body image, and health benefits. The mean score for the expected outcomes/benefits questions were 4.08±0.62. The subscale data for physical activity outcome expectations are presented in Table 8. Correlations between physical activity and expected outcomes/benefits are presented in Table 9. There was a significant relationship between physical activity that was ≥3METs and ≥ 1 minute bouts and psychological benefits (r=0.33, *p*=0.048) (Appendix I Figure 15). There was also a significant relationship between physical activity that was 3METs and $\geq$ 10 minute bouts and psychological benefits (r=0.34, p=0.04). However, there were no other significant relationships observed.

Additionally, a Kruskal-Wallis ANOVA was conducted to examine expected outcomes differences between the three physical activity groupings (150 minutes per week, 150-249 minutes per week, and $\geq$250 minutes per week). Analyses revealed no significant difference in total expected outcomes (benefits) between the three physical activity groups (Table 10).

Physical Activity Perceived Barriers

Data from physical activity perceived barriers were divided into an overall total score (perceived barriers), with subscales of time, effort, and obstacles barriers. The mean score for the perceived barriers questions was 2.45 ±0.60. The subscale data for physical activity perceived barriers are presented in Table 8. Correlations between physical activity and perceived barriers are presented in Table 9. A trend towards a significant relationship was observed between physical activity ($\geq$3METs and $\geq$ 1 minute) and time barriers (r=0.32, p=0.053) (Appendix J Figure 16).

A Kruskal-Wallis ANOVA was conducted to examine perceived barriers between the three physical activity groupings (150 minutes per week, 150-249 minutes per week, and $\geq$250 minutes per week). No significant difference was observed for total perceived barriers between the 3 physical activity groups (Table 10).

HRQOL

The overall result for HRQOL showed a mean score of 59.46 ± 0.92 out of a possible score of 100 (Table 8). Correlations between physical activity and HRQOL are presented in Table 9. No significant correlation between physical activity of $\geq$3METs and $\geq$ 1minute bouts (Appendix K Figure 17) or $\geq$3METs and $\geq$ 10 minute bouts and HRQOL were observed.

A Kruskal-Wallis ANOVA was conducted to examine HRQOL between the three physical activity groupings (150 minutes per week, 150-249 minutes per week, and $\geq$ 250 minutes per week). No significant difference was observed for HRQOL between the 3 physical activity groups (Table 10).

5.0 DISCUSSION

5.1 INTRODUCTION

The primary purpose of this study was to characterize the physical activity profile of subjects who are 2-5 years post bariatric surgery. This study focused on examining the following specific aims:

1. To describe physical activity levels (minutes/week of moderate to vigorous activity) in individuals 2-5 years post weight loss surgery.
2. To examine the association between level of physical activity and level of weight loss in individuals 2-5 years post bariatric surgery.
3. To examine the association between physical function and physical activity in individuals 2-5 years post bariatric surgery.
4. To examine the association between physical function and amount of weight loss in individuals 2-5 years post bariatric surgery.
5. To examine the association between psychosocial correlates of physical activity and level of physical activity in response to bariatric surgery.

5.2 PERCENT EXCESS WEIGHT LOST

The demographic characteristics of the subjects in this study are typical of the wider population of post-bariatric surgery patients (17). In a comprehensive review by Buchwald et al. (16), patients undergoing bariatric surgery were overwhelmingly female, with a mean age of 38.97 years (range, 16.20-63.8 years). Based on data from this review the mean percentage of excess weight loss (%EWL) at 2 years post gastric bypass surgery was 61.6% (range 56.7%-66.5%). On average, subjects in this study lost 62.2 ±19.9% of their excess weight; however, the range of weight loss was broad (24.3%-93.1%). The mean %EWL in this current study is similar to what has previously been reported; however, the range of %EWL appears to be somewhat broader than the prior studies.

5.3 SPECIFIC AIM 1: TO DESCRIBE PHYSICAL ACTIVITY LEVELS (MINUTES/WEEK OF MODERATE TO VIGOROUS ACTIVITY) IN INDIVIDUALS 2-5 YEARS POST BARIATRIC SURGERY.

On average subjects in this study participated in 205 ± 137 min/wk of moderate to vigorous activity ($\geq$3METs) at 2-5 years post bariatric surgery. Interestingly, there was a wide range of physical activity levels observed (20-528 minutes per week). Sixty three percent (23 of 36 subjects) of the subjects participated in >150 minutes of moderate to vigorous intensity activity defined as $\geq$3METs, while 37 percent (13 out 36 subjects) were at or below 150 minutes. Previous research conducted by Josbeno et al. (132) reported that physical activity levels were 191 ± 228 min/wk and 232 ± 239 min/wk in obese patients when evaluated prior to and 3 months following bariatric surgery, respectively. Taken in this context, it would appear that physical activity remains relatively stable in this population from pre-surgery to $\geq$2 years post surgery. There are differences which should be considered when comparing results across these studies. The main difference between studies is the methods used to assess physical activity. Josbeno et al. (132) used a 7 day physical activity recall, whereas in this current study an objective method was used to assess physical activity (SenseWear® Pro armband, BodyMedia, Inc.). Overweight and obese individuals have been shown to over-report physical activity, and self-reports have been shown to be subject to social desirability (i.e. reporting "good" behaviors) and recall bias (inaccurately recalling frequency and duration of activity) (110;133). These reporting process errors may have inflated the physical activity levels in our prior study thereby limiting a meaningful comparison of physical activity levels between these studies. To best understand the long term pattern of change in physical activity levels following bariatric surgery it may be important to include objective measures in future studies.

The physical activity data in this current study (205.33 ±136.98 min/wk) reflect total minutes of activity at an energy expenditure of $\geq$3METs. However, current physical activity guidelines (134) recommend that activity bouts be sustained for $\geq$ 10 minutes to elicit significant health benefits. When data from the SenseWear® Pro armband were analyzed to identify levels of physical activity that met the criteria of $\geq$3METs for $\geq$10 minutes in duration, the total physical activity per week was 47.56 ± 69.84 min/wk. A potential explanation for this finding may be found in the advice provided to these patients by their healthcare providers. In this study, subjects were asked to recall the activity recommendations they received after surgery. Interestingly, there was a high degree of variability in post-surgical physical activity recommendations (Table 6). Eleven people did not recall receiving any instruction and amongst the 26 remaining subjects, there was a large disparity in the recommended frequency of physical activity. One explanation for this inconsistency could be a failure of the subjects to remember the recommendations after 2-5 years. This lack of recall could also be due to ineffective communication of the post surgical weight maintenance program. This assertion is supported in a recent study by Davis et al. (135) which concluded that the weight loss education varied in effectiveness with obese, medically complex patients. The authors found that only 28% of the patients were able to recall the exercise/activity recommendations provided by their physicians. As a part of the study, an intervention designed to improve weight loss counseling (including eating/diet and activity/exercise domains) was administered. Patient recall improved significantly to 69% after the intervention (135). Thus, it may be important to educate healthcare providers on the importance of physical activity for their patients and to encourage appropriate post-operative counseling to maximize long-term weight loss outcomes.

5.4 SPECIFIC AIM 2: TO EXAMINE THE ASSOCIATION BETWEEN LEVEL OF PHYSICAL ACTIVITY AND LEVEL OF WEIGHT LOSS IN INDIVIDUALS 2-5 YEARS POST BARIATRIC SURGERY.

It was hypothesized that physical activity would be significantly correlated with %EWL at 2-5 years post bariatric surgery. This study showed that %EWL was significantly ($p<0.05$) correlated with physical activity defined as total min/wk that met the criteria of $\geq$3METs ($r=0.47$) and when bouts of activity were defined as $\geq$3METs sustained for $\geq$10 min/wk ($r=0.35$). Moreover, %EWL was significantly greater in subjects participating in $\geq$250 min/wk of physical activity compared to those subjects participating in <150 min/wk of physical activity (Table 10 and Figure 7). Thus, based on the findings, the hypothesis is accepted and supports the conclusion that physical activity is significantly correlated with %EWL at 2-5 years post bariatric surgery.

These findings are consistent with results from previous studies that have examined the association between physical activity and long-term weight loss following bariatric surgery

(39;40;108;136). For example, Bond et al. (40) examined physical activity participation in 1585 patients who had gastric bypass surgery. Physical activity was assessed using a "yes / no" self-report to indicate participation in physical activity, but did not quantify the level of physical activity or energy expenditure. Their findings showed that, at 2 years post gastric bypass surgery, patients who reported physical activity participation had greater weight loss (68.2±17.4 %EWL) compared to patients who did not report participating in structured physical activity (63.9 ± 19.5 %EWL). Moreover, Evans et al. (136) reported that patients who participated in a minimum of 150 minutes per week of moderate or higher intensity physical activity achieved the greatest postoperative weight loss at 12 months post bariatric surgery. The %EWL was 67.4%±14.3% at 12 months for those who participated in >150 min/wk and 61.7%±17.0 in the <150 minutes per week group. Their results appear to be comparable to the findings observed in this current study. As shown in Figure 7, when subjects were grouped as participating in <150, 150-249, or ≥250 min/wk the %EWL was 52.9±18.0, 66.7±22.7, and 68.8 ±16.8, respectively. These results appear to support the importance of sufficient doses of moderate to vigorous physical activity to enhance long term weight loss post-bariatric surgery.

The importance of physical activity for long term weight loss has also been shown in studies that have not involved bariatric surgery (105). For example, Jakicic et al. (106;137) showed significantly improved weight loss at 12 months when subjects participated in ≥200 min/wk; and 24 month weight loss was significantly improved with the addition of ≥275 min/wk of moderate to vigorous physical activity. Similar results were reported by Ewbank (138) and Schoeller et al. (102;138). These findings are also consistent with the recent physical activity recommendations of the American College of Sports Medicine that 250-300 min/wk will improve long term weight loss and enhance prevention of weight regain (134). The ACSM guidelines are also consistent with the recommendations in the 2005 US Dietary Guidelines (46).

5.5 SPECIFIC AIM 3: TO EXAMINE THE ASSOCIATION BETWEEN PHYSICAL FUNCTION AND PHYSICAL ACTIVITY IN INDIVIDUALS 2-5 YEARS POST BARIATRIC SURGERY.

This study did not demonstrate a relationship between physical function and physical activity level, which was consistent with previous work in a bariatric surgery population (132) in which physical function was assessed using this domain from the SF-36 questionnaire. In this current study total min/wk of objectively measured physical activity $\geq$3METs was not significantly correlated with the physical function domain ($r=0.20$, $p=0.24$). Thus, the results from the current study reject the hypothesis that there would be a significant association between physical function and physical activity in patients at 2-5 years post-bariatric surgery. Similar results were observed in our prior study at 3 months post-bariatric surgery in which the physical function domain from the SF-36 was also not significantly correlated with self-reported physical activity ($r=0.40$, $p=0.11$) (132).

The lack of a significant association being observed between physical function and physical activity post-bariatric surgery may be a result of the use of a questionnaire to assess physical function in this current study. The use of objective, performance-based measures may have resulted in a different finding and conclusion. For example, in our previous study we used performance-based measures to assess physical function that included a 6 minute walk test and the Short Physical Performance Battery. When these measures were used a significant association ($p<0.05$) between level of physical activity and both the 6 Minute Walk Test ($r=0.60$) and the Short Physical Performance Battery ($r=0.55$) was observed. The current study assessed physical function using a self report questionnaire. This measure identified the subjects' perception of their capability to complete an activity and may not have accurately reflected their true capability as was found in the above referenced study.

The finding that physical activity was not related to physical function is also in contrast to previously reported studies which involved older adults (55;139;140). Brach et al. (55) examined the relationship among physical activity, physical function and obesity in older community dwelling women (mean age 72). They observed that overweight/obese women reported more difficulty with activities of daily living (ADLs) and had decreased gait speed. When the groups were stratified for weight and activity level (normal weight/active, normal weight /inactive overweight/obese active and overweight /obese inactive) the overweight/obese group who reported they were active also reported physical function level similar to the normal weight/inactive group. This resulted in the authors suggesting that physical activity is related to physical function.

Data from the Women's Health and Aging Study (WHAS), which involved moderately to severely disabled community-dwelling women $\geq$ 65 years, suggested that women who perceive they have difficulty walking will be less active than those who perceive they are capable of walking (141). Data from this current study does not support this finding as subjects' perception of their functional capabilities was not significantly correlated with physical activity suggesting that those who perceived they were functionally fit were not necessarily more physically active. Subjects in this present study may have an incorrect perception of their capabilities due to the benefits of bariatric surgery, and this may have resulted in subjects perceiving themselves to have a higher level of physical function than would have been detected if performance-based tests had been included in this study. This inaccurate perception may be a result of factors such as reduction of medical comorbid conditions (72), reduction of pain (132), improvement in quality of life (67), and reduced stress placed on the body due to weight loss, all of which may have contributed to the perception of improved physical function.

5.5.1 Specific Aim 4: To examine the association between physical function and amount of weight loss in individuals 2-5 years post bariatric surgery.

The results from this study showed that %EWL at 2-5 years post-bariatric surgery is significantly associated with self-reported physical function ($r=0.35$, $p=0.03$). This finding supports the research hypothesis that individuals who report a greater level of physical function will have greater weight loss 2-5 years post bariatric surgery, and therefore the hypothesis is accepted.

The results of this current study are consistent with prior research showing that lower body weight is associated with improved levels of physical function (the ability to perform mobility tasks and activities of daily living). For example, these studies have reported that adults with greater levels of obesity have poorer physical function compared to their lean counterparts (142-144). Larsson et al.(9) reported that obese women perceived and demonstrated greater disability in tasks such as personal hygiene, ADL performance, housework that required squatting or lifting, and walking or stair climbing as compared to normal weight women. These cross sectional studies provide evidence that obesity is related to physical limitations and impaired function, and suggested that lower body weight may improve physical function.

A potential limitation of this current study is the cross-sectional design, which did not allow for the prospective examination of how weight loss induced with bariatric surgery improves physical function in obese adults. However, prior investigations have demonstrated that weight loss induced by bariatric surgery can improve function in this population (132;145). Moreover, Miller et al. reported improvements in physical function (performance and self reported) at 3 weeks, 3 months, 6 months and 12 months post surgery without exercise training (146).

The %EWL in this study at 2-5 years post-bariatric surgery was 62.2±19.9, and this magnitude of %EWL is similar to the magnitude reported by others following bariatric surgery

(16). However, there is evidence that physical function can improve with even lower levels of weight loss. Miller et al. demonstrated that modest weight loss (5-10%) in conjunction with an exercise intervention improved physical function in overweight and obese older adults with knee osteoarthritis (147). In a study performed as a Thesis Project at the University of Pittsburgh, Weary reported significant a 7.6% improvement in sit-to-stand performance following a 12-week behavioral intervention that resulted in a 5.9% weight loss.

5.6 SPECIFIC AIM 5: TO EXAMINE THE ASSOCIATION BETWEEN PSYCHOSOCIAL VARIABLES OF PHYSICAL ACTIVITY AND LEVEL OF PHYSICAL ACTIVITY IN RESPONSE TO BARIATRIC SURGERY.

Self-Efficacy and Physical Activity: A significant ($p<0.05$) relationship was found between physical activity and total self-efficacy score ($r=0.39$) and sub-scores of participation in physical activity when tired ($r=0.40$) and low on time ($r=0.43$). There were also trends towards a significant ($p<0.08$) relationship between min/wk physical activity $\geq$3METs and self-efficacy sub-scores to participate in physical activity when in a bad mood ($r=0.30$), when on vacation ($r=0.31$), or in bad weather ($r=0.30$). These findings support the research hypothesis that individuals who report a greater level of self-efficacy for physical activity will have participated in a greater level of physical activity 2-5 years post bariatric surgery; therefore this hypothesis is accepted.

The finding that self-efficacy is correlated with physical activity level is consistent with previously reported studies. Omen et al. examined the influence of physical activity self-efficacy among healthy sedentary adults who participated in a supervised home based exercise program and found that baseline self-efficacy significantly predicted exercise adherence at the 2 year follow-up assessment (118). In a study of non-surgical weight loss in overweight and obese women, Gallagher et al. reported that baseline self-efficacy for physical activity was not significantly associated with physical activity following a 6 month intervention; however, 6 month physical activity self-efficacy was significantly associated with 6 month physical activity level (r=0.30), which is similar to the magnitude of associations reported in this current study. Moreover, Gallagher et al. reported that physical activity self-efficacy was 2.98±0.78 and improved to 3.24±0.74 at 6 months, which is similar to the level found in this current study of bariatric surgery patients (3.02±1.13) (45). Collectively, data from this study and previous findings would suggest that a behavioral intervention targeted to improve physical activity self-efficacy would be important for increasing physical activity in overweight and obesity adults regardless of weight loss method (i.e. surgical or behavioral).

<u>Outcome Expectations:</u> The results of this study showed that total min/wk of physical activity at $\geq$3METs was significantly associated with the outcome expectation that physical activity would improve psychological benefits ($r=0.33$, $p<0.05$). However, there was not a significant correlation between physical activity and the expectations that physical activity would improve image, health, or total expected outcomes. Thus, based on these results, the hypothesis that the outcome expectation for psychological benefits being associated with physical activity is accepted; whereas the hypothesis that image, health, and total expected outcomes being associated with physical activity is rejected.

The finding that outcome expectation was not associated with physical activity was consistent with previous studies. Josbeno et al. reported that outcome expectations were not significantly related to physical activity in obese patients when evaluated pre-operatively and at 3 months following bariatric surgery (-0.23 and -0.16 respectively) (132). Gallagher et al also reported similar results for overweight and obese subjects who participated in a non-surgical weight loss intervention (45). The authors reported no significant correlations between either baseline or 6 month outcome expectations or subjects' level of physical activity at 6 months post intervention. Interestingly, Gallagher also points out that the only change following the intervention was an increase in the perceived psychological benefits (3.66 ±0.87 to 3.76 ± 0.84). There were minimal changes in the outcome expectations (benefits) achieved from physical activity at 6 months (4.21 ±0.61 to 4.27 ±0.60) (45). These results paralleled those found in the current study when patients were 2-5 years post surgery (4.08 ±0.62).

Together, these studies suggest that while individuals may understand the potential benefits of physical activity, knowledge alone was not sufficient to drive a change in behavior.

Perceived Barriers: The results of this study showed a trend for a significant correlation between the total min/wk of physical activity at ≥3METs and time barriers (p=0.053). However, a relationship was not found when physical activity was correlated with effort (p=0.14), obstacles (p=0.40) or total perceived barriers (p=0.93). Thus, based on these results, the hypothesis that perceived barriers are associated with physical activity is rejected.

This finding is consistent with Josbeno et al. who also found perceived barriers were not significantly related to physical activity in obese patients when evaluated pre-operatively and at 3 months following bariatric surgery (0.23 and -0.29 respectively). The reported barriers to physical activity were unchanged before and after surgery (2.6 ±0.50 and 2.7 ±0.48, respectively) (132). This could be explained by the fact that subjects in this study did not receive focused interventions to specifically address the time, effort or obstacles barriers.

Gallagher et al. reported contrasting results. Similar to the Josbeno et al study, they found no baseline correlation between perceived barriers and physical activity. However, in response to a 6-month behavioral weight loss intervention, they found both a significant correlation between 6-month physical activity and time barriers (r=-0.17, p<0.05) and a significant reduction in perceived barriers (2.89 ± 0.68 to 2.33 ±0.69) (45). This study and the previously referenced studies suggest that a behavioral intervention that focuses on reducing barriers of physical activity might be important for increasing physical activity after bariatric surgery.

HRQOL: HRQOL was not found to be correlated with the level of physical activity. Based on this result, the hypothesis that HRQOL is associated with physical activity is rejected. This finding is consistent with Josbeno et al who reported that HRQOL was not significantly related to physical activity in obese patients neither pre-operatively (r=-0.17, *p*=0.46) nor at 3 months after surgery (0.47, *p*=0.06). Interestingly, subjects reported an increase in HRQOL (38.2 ± 23.58 to 89.7 ± 15.53, *p*= 0.00) after bariatric surgery. These improvements paralleled those seen in their physical performance and a reduction in pain, yet they did not change their level of physical activity (132). While it has been shown that quality of life improves significantly after weight loss following bariatric surgery(148), this increase may not influence physical activity.

5.7 LIMITATIONS AND FUTURE RESEARCH

This study is not without limitations which could impact the application of the observed results. The following limitations and recommendations should be considered for future research:

1) Due to the cross-sectional design of this study causality cannot be established. There was limited data on the subjects' baseline information such as pre-surgical physical activity level, physical function capabilities, exercise levels and dietary habits. Such measurements might have provided information that could explain how these variables may have changed due to the results of the surgery. Therefore results of this study need to be validated in a prospective cohort. A prospective long term study with follow-ups (e.g. physical activity assessments, assessment of physical function status and weight loss) will allow us to further investigate the relationships between

physical activity and bariatric surgery outcomes. Additionally, to provide evidence of the effectiveness of physical activity for successful long term surgical outcomes, future studies should involve randomization of subjects to various levels of physical activity after bariatric surgery. This information will assist in defining evidence-based physical activity guidelines for post bariatric surgery patients.

2) Physical activity was assessed using the BodyMedia SenseWear® Pro armband as an objective measurement of physical activity. While this monitor has been shown to provide accurate objective data on energy expenditure in healthy, relatively young, normal weight adults (123;124), the BodyMedia SenseWear® Pro armband has not undergone extensive validation in a bariatric surgery population. Research may need to be conducted to establish the validity of the BodyMedia SenseWear® Pro armband for this group.

3) This study assessed physical function using a self report measure. Future studies should examine if a self-report measure of physical function provides similar information as performance-based measures in this population, and if the association with physical activity participation would be similar when either measurement technique is used.

4) The assessment of perceived barriers to physical activity in the present study was determined by using a questionnaire that was validated in a college and work site population. This questionnaire may not have captured the actual barriers for individuals who have undergone bariatric surgery. Future research is recommended to identify specific barriers related to this population. This could lead to development of an assessment tool targeted to the barriers present in this population.

5) Compliance to dietary recommendations may have contributed to the %EWL observed in these subjects. However, dietary intake was measured as a descriptive

variable in this study and was assessed using a food frequency questionnaire. In this study, no significant relationship was seen between % EWL and energy intake. However, there was a significant correlation between daily caloric intake and physical activity that was $\geq$3METs and $\geq$10 minute bouts ($r=-0.35$, $p=0.04$). Future studies should include an examination of dietary habits in combination with physical activity to determine how total these factors influence energy balance and contribute to long-term weight loss following bariatric surgery. Moreover, dietary measures other than a food frequency questionnaire may need to be used to provide a valid assessment of dietary intake in this population.

6) The sample was limited to subjects 2-5 years post bariatric surgery. It is unclear how these results would compare to findings of individuals are $\geq$5 years post-bariatric surgery. Therefore, future studies should consider examining individuals in an expanded period of time post-bariatric surgery.
7) This study was limited to individuals who had bariatric surgery in the form of gastric bypass. It is unclear if similar results would be observed for patients if alternative bariatric surgery procedures were used (i.e. lap band). Future studies should consider examining physical activity and physical function across an array of bariatric surgery procedures.
8) While the investigator made every attempt to recruit a diverse group of subjects, ultimately subjects self-selected to participate in this study. This may have resulted in selection bias with regard to weight loss, physical activity, and physical function. Future studies should attempt to address this potential selection bias.

5.8 CONCLUSION

It is well established that physical activity is essential for weight loss maintenance in the non-surgical population. Evidence is mounting that physical activity is a significant contributor to weight loss maintenance in individuals who had surgical intervention for obesity. While weight loss as a result of bariatric surgery appears to contribute to improved physical function, there is a lack of evidence showing a direct relationship to increased physical activity. Likewise, an increase in physical activity does not necessarily result in improved physical function in this population. This disparity between physical activity and physical function would suggest that the barriers to the adoption of a more physically active lifestyle are not related to their capabilities. Given that subjects are capable of performing most functional activities following bariatric surgery, the rate limiting factors seem to be related more to their attitudes and perceptions, rather than their physical abilities.

Moreover, despite the significant association found between physical activity and %EWL, few bariatric surgery patients met the current CDC guidelines on the physical activity standards that have been shown to result in health benefits and disease prevention. When using the recommendation that physical activity should be moderate to vigorous in intensity (3METs) and at least 10 minute bouts in duration, less the 23% of these subjects reported activity patterns at that level. Thus, intervention strategies targeting self-efficacy, psychological benefits of physical activity and time barriers are needed to change the physical activity profiles of individuals following surgical intervention.

After choosing to undergo a rather significant surgical procedure, a desirable effect would be that individuals *choose* to make healthy lifestyles changes. While seemingly simple, this and other studies continue to demonstrate the multi-dimensional nature of the challenge of changing behavior, and this may be particularly important to study in patients who undergo bariatric surgery.

APPENDIX A

RECRUITMENT FLIER

INDIVIDUALS WHO HAVE UNDERGONE WEIGHT LOSS SURGERY BETWEEN 2 OR MORE YEARS AGO ARE NEEDED FOR A RESEARCH STUDY LOOKING AT ACTIVITY HABITS

Researchers at the University of Pittsburgh Departments of health and Physical Activity and Physical Therapy are looking for individuals:

- Who have undergone weight loss surgery 2 -5 years ago
- Who have not undergone weight surgery revision
- Who are at least 18 years of age or older
- Who has not been pregnant within the last 6 months

All individuals who meet the criteria will participate in an assessment of their physical activity which involves wearing an armband for 7 consecutive days and questionnaires on your exercise and dietary habits.

APPENDIX B

SCRIPT FOR RECRUITMENT

Research Opportunity

The Relationship between Physical Activity, Physical Function and Psychosocial Variables in Individuals 2 to 5 Years Post- Bariatric Surgery.

University of Pittsburgh Department of Physical Therapy

University of Pittsburgh Department of Health and Physical Activity

- Mr./Ms.________, I wanted to tell you about a study that is being done that looks at the physical activity level in people who had the same surgery that you have had. People who seek bariatric surgery are often motivated to improve their physical health and this study will allow us to investigate how active you after your surgery.

- If you agree to participate in this study, the researchers will assess how active you are and your exercise and eating habits. You will also wear an activity monitor around your upper arm for 7 days to record your daily activity.

- If you are interested in participating in this study, I will introduce you to one of the investigators (or pleased call one of the investigators) for this study. She will further explain the details to you in more depth.

Inclusion Criteria	*Exclusion Criteria*
• Female or Male • ≥ 18 years of age • Able to provide verification that he/she had had bariatric surgery 2-5 years, Bariatric surgical procedures may include GBS, gastric banding, vertical banded gastroplasty, sleeve gastrectomy, etc) • Able to come to testing site for assessment • Able to provide informed consent	• Have undergone bariatric surgery revision • pregnant within the last 6 months • Unable to ambulate 150 feet (50 yards) independently • Unable to tolerate wearing an armband on the right upper arm

APPENDIX C

SCRIPT FOR RESEARCH OPPORTUNITY

The Relationship between Physical Activity, Physical Function and Psychosocial Variables in Individuals 2 -5 Years Post- Bariatric Surgery.

University of Pittsburgh Department of Physical Therapy

University of Pittsburgh Department of Health and Physical Activity

- Mr./Ms.________, I wanted to tell you about a study that is being done that also looking physical activity level in people who had the same surgery that you have had.

- If you agree to participate in this study, the researchers will also look at how active you are and your exercise and dietary habits. In addition to wearing the activity monitor armband that you are doing for this study you will be asked to complete questionnaires on your health and exercise habits.

- If you are interested in participating in this study, I will introduce you to one of the investigators (or pleased call one of the investigators) for this study. She will further explain the details to you in more depth.

APPENDIX D

SCREENING FORM AND SCRIPT

- Thank you for calling to find out more about our research study. My name is _______ and I am a physical therapist and a doctoral student working on this study. This study will look at the physical activity level in people who had the same surgery that you have had. People who seek bariatric surgery are often motivated to improve their physical health and this study will allow us to investigate how active you after your surgery. In order to assess how active you are during the day you will be asked to wear an activity monitor armband for 7 consecutive days that we will loan to you. Your height and weight will also be taken and you will be asked to complete questionnaires on your health and exercise and dietary habits. In order to determine if you are eligible to participate in the study, I would like to ask you a few questions about your medical history and ability to perform the assessments. You don't have to answer any of these questions if you don't want tp. There is a rare possibility (less than 1%) that confidentiality of this phone conversation could be breached however, the information that I receive from you by phone will be kept confidential. The purpose of these questions is to determine whether you are eligible for our study. If you are eligible for the study, I will schedule an appointment for the assessment with you at the end of this phone call. Remember, your participation is voluntary; you do not have to complete these questions, If it is determined that you are ineligible for the study, all information obtained during this phone conversation will be immediately destroyed.
- Do I have permission to ask you these questions?

    If no: Thank you very much for calling

    If yes:

    What is your name? ____

    What is your age? ____

    What is your address? ____

    ____

    ____

What is your phone number that you preferred to be reached at?

____

When did you have your surgery for weight loss? _______________________

What type of procedure did you have? Circle one: GBS GB VBG BPD

Have you undergone a surgical revision for your weight loss surgery? _____

Would you be able to obtain verification of the date and procedure performed and your pre-surgery weight from your surgeon or primary care physician? ____________

Would you allow us to contact your surgeon or primary care physician to obtain verification of the date and procedure performed? ______________________

What is your surgeon's name and contact name? Name: ________________
Number: _______________

Have you been pregnant within the last 6 months? _____________________
Are you able to walk 150 feet or more by yourself? _____________________
Will you be able to tolerate wearing an activity monitor armband with a Velcro strap on your right upper arm for 7 days? ____________________________________

Thank you for answering these questions. Do you have any other questions for me?

- -

If the individual is eligible they will be entered into the study and scheduled for the assessment. They will be offered various locations (Oakland or Southside) or if possible evaluated at the Minimally Invasive Surgery Center at the Magee-Womens Hospital of UPMC

APPENDIX E

CORRELATION BETWEEN PHYSICAL ACTIVITY AND WEIGHT LOSS

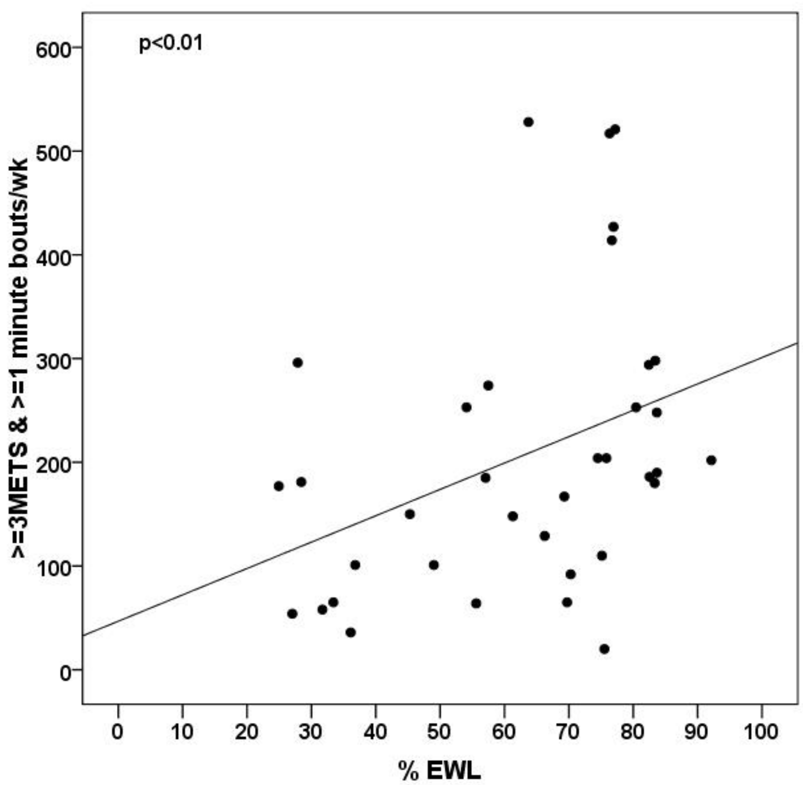

Figure 9: Correlation between physical activity (>/=3 METs & >/= 1 minute bouts) and %EWL

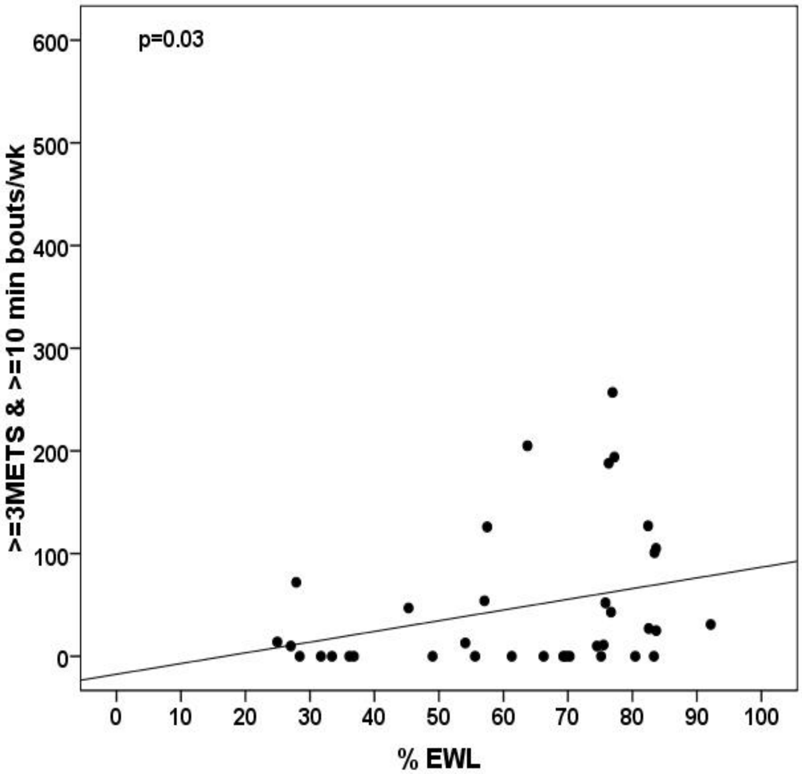

Figure 10: Correlation between physical activity (>/= 3METs &>/= 10 minute bouts) & %EWL

APPENDIX F

CORRELATION BETWEEN PHYSICAL ACTIVITY AND PHYSICAL FUNCTION

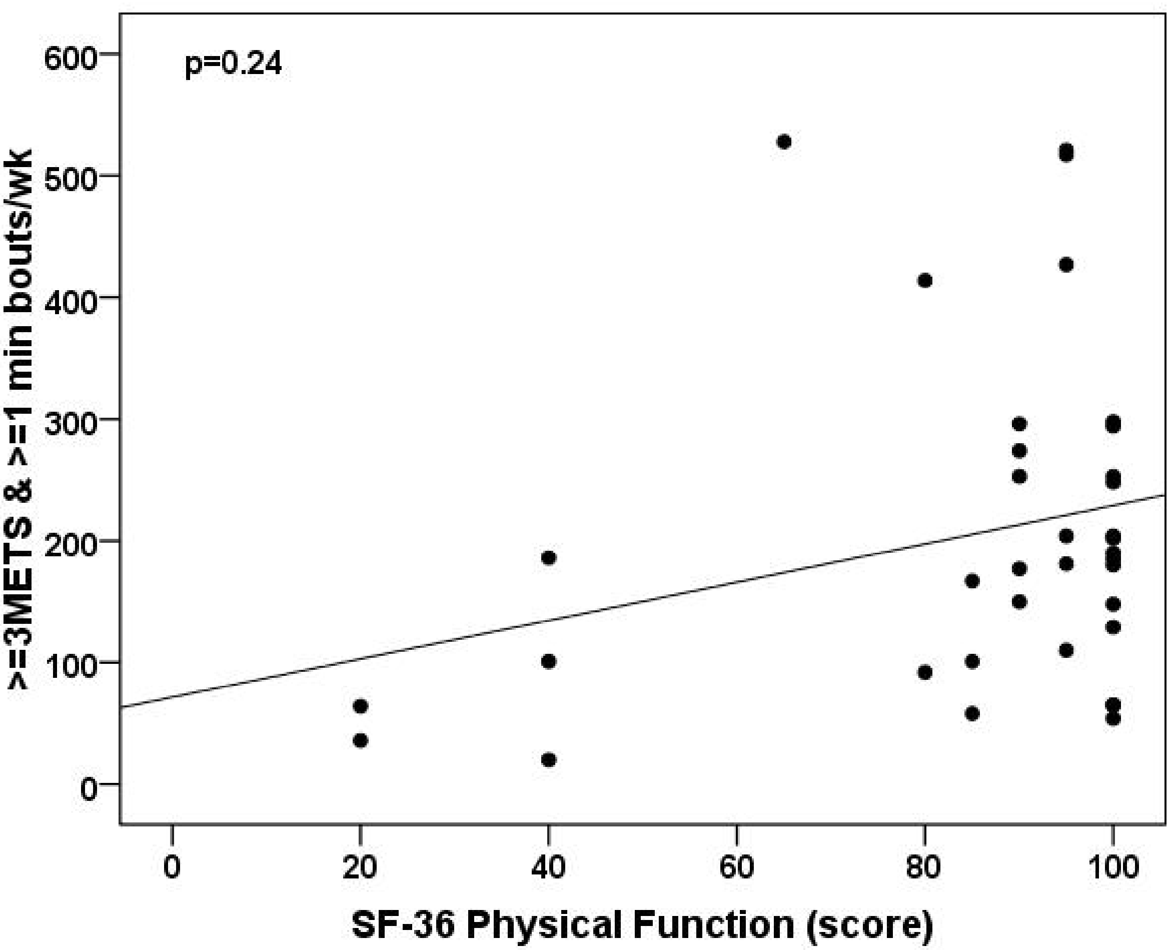

Figure 11: Correlation between physical activity and physical function

APPENDIX G

CORRELATION BETWEEN PHYSICAL FUNCTION AND %EWL

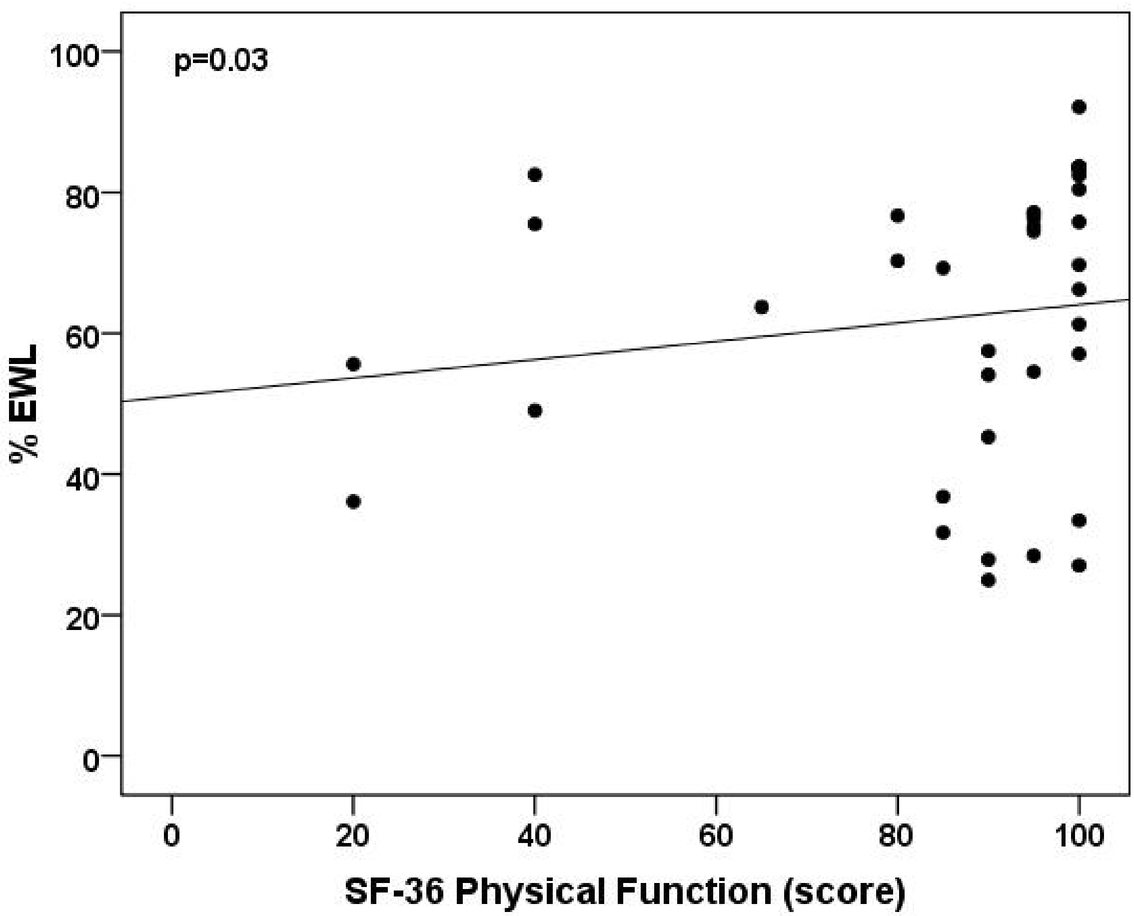

Figure 12: Correlation between physical function and %EWL

APPENDIX H

CORRELATION BETWEEN PHYSICAL ACTIVITY AND SELF-EFFICACY

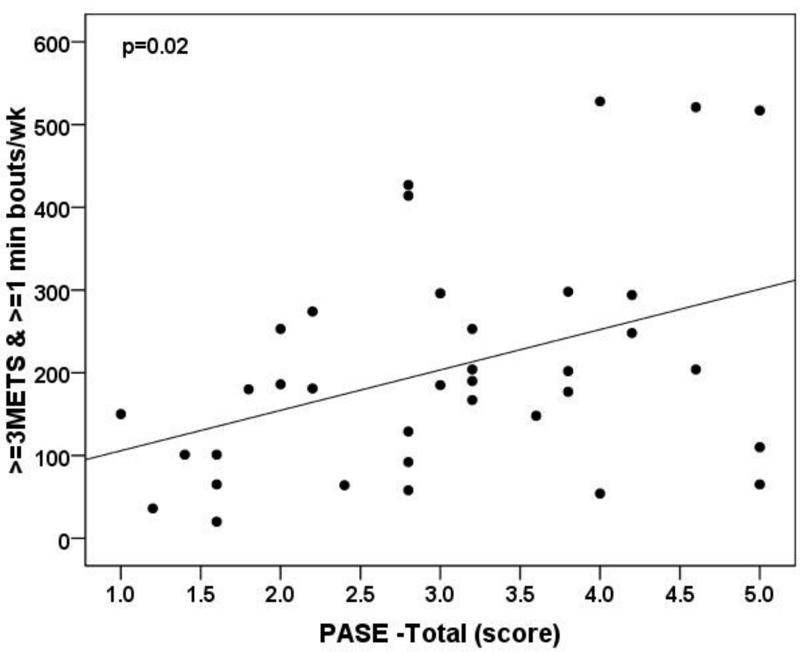

Figure 13: Correlation between physical activity (>/= 3 METs &>/= 1 minute bouts) and self-efficacy

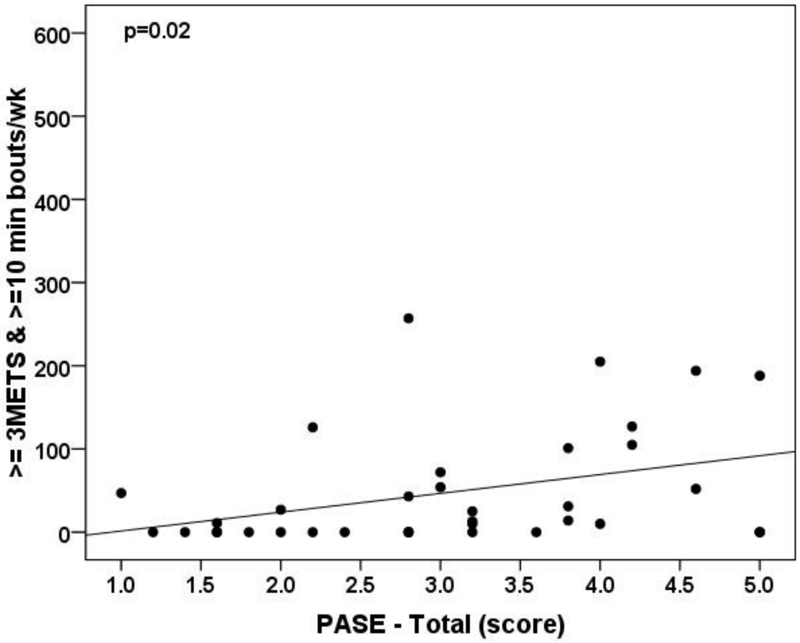

Figure 14: Correlation between physical activity (>/= 3 METs &>/= 10 minute bouts) and self-efficacy

APPENDIX I

CORRELATION BETWEEN PHYSICAL ACTIVITY AND PSYCHOLOGICAL BENEFITS

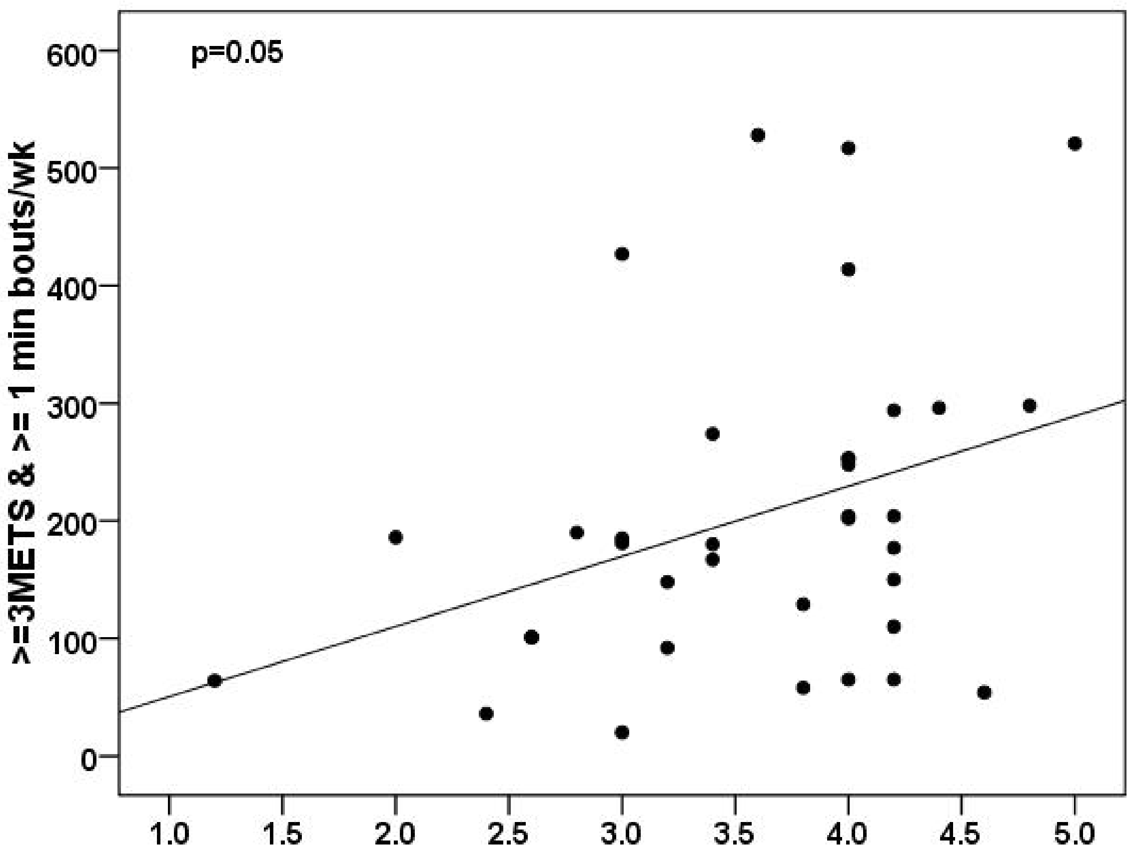

Figure 15: Correlation between physical activity and psychological benefits

APPENDIX J

CORRELATION BETWEEN PHYSICAL ACTIVITY AND TIME BARRIER

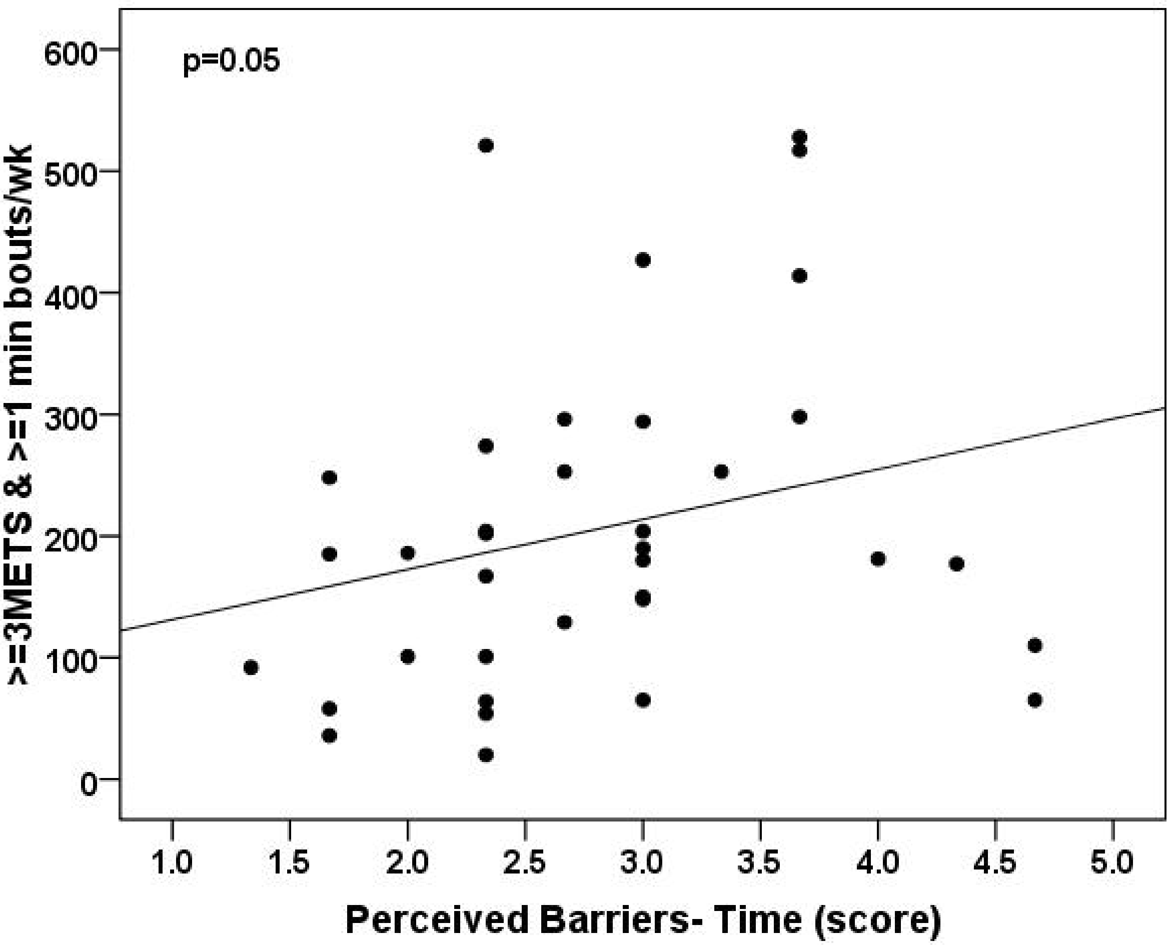

Figure 16: Correlation between physical activity and time barrier

APPENDIX K

CORRELATION BETWEEN PHYSICAL ACTIVITY AND HRQOL

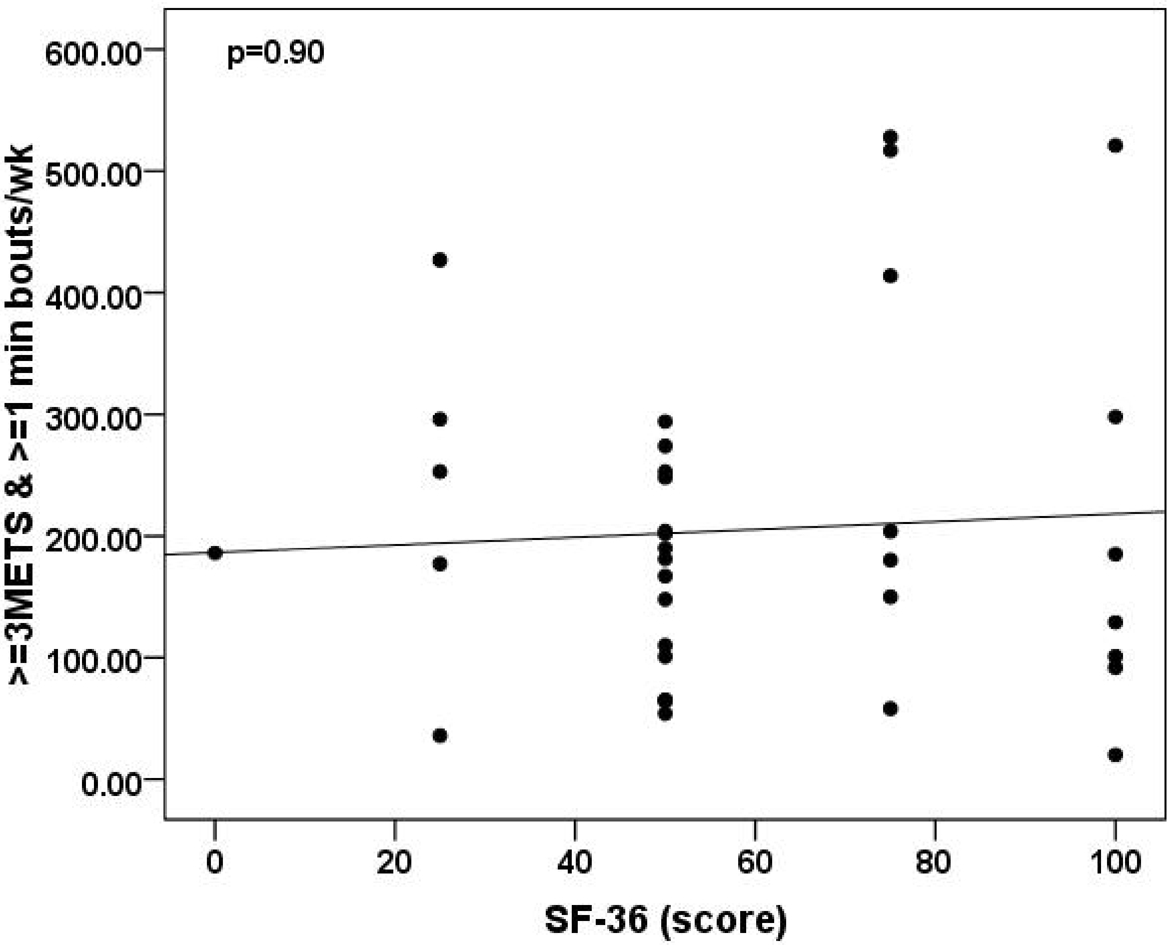

Figure 17: Correlation between physical activity and HRQOL

BIBLIOGRAPHY

(1) Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. JAMA 295(13):1549-55, 2006.

(2) Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999-2000. JAMA 288(14):1723-7, 2002.

(3) Sturm R. Increases in clinically severe obesity in the United States, 1986-2000. Archives of Internal Medicine 163(18):2146-8, 2003.

(4) Freedman DS, Khan LK, Serdula MK, Galuska DA, Dietz WH. Trends and correlates of class 3 obesity in the United States from 1990 through 2000. JAMA 288(14):1758-61, 2002.

(5) Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The disease burden associated with overweight and obesity. JAMA 282(16):1523-9, 1999.

(6) Fontaine KR, Redden DT, Wang C, Westfall AO, Allison DB. Years of life lost due to obesity. JAMA 289(2):187-93, 2003.

(7) Flegal KM. Epidemiologic aspects of overweight and obesity in the United States. Physiology & Behavior 86(5):599-602, 2005.

(8) Mokdad AH, Ford ES, Bowman BA, Dietz WH, Vinicor F, Bales VS et al. Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. JAMA 289(1):76-9, 2003.

(9) Larsson UE, Mattsson E. Perceived disability and observed functional limitations in obese women. International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity 25(11):1705-12, 2001.

(10) Larsson UE. Influence of weight loss on pain, perceived disability and observed functional limitations in obese women. International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity 28(2):269-77, 2004.

(11) Peeters A, Bonneux L, Nusselder WJ, De Laet C, Barendregt JJ. Adult obesity and the burden of disability throughout life. Obesity Research 12(7):1145-51, 2004.

(12) Wearing SC, Hennig EM, Byrne NM, Steele JR, Hills AP. Musculoskeletal disorders associated with obesity: a biomechanical perspective. Obesity Reviews 7(3):239-50, 2006.

(13) Kolotkin RL, Crosby RD, Williams GR. Health-related quality of life varies among obese subgroups. Obesity Research 10(8):748-56, 2002.

(14) Bocchieri LE, Meana M, Fisher BL. Perceived psychosocial outcomes of gastric bypass surgery: a qualitative study. Obesity Surgery 12(6):781-8, 2002.

(15) Arterburn DE, Maciejewski ML, Tsevat J. Impact of morbid obesity on medical expenditures in adults. Int J Obes Relat Metab Disord 29(3):334-339,2005.

(16) Buchwald H, Avidor Y, Braunwald E, Jensen MD, Pories W, Fahrbach K et al. Bariatric surgery: a systematic review and meta-analysis. JAMA 292(14):1724-37, 2004.

(17) Santry HP, Gillen DL, Lauderdale DS. Trends in bariatric surgical procedures. JAMA 294(15):1909-17, 2005.

(18) Steinbrook R. Surgery for severe obesity. New England Journal of Medicine 350(11):1075-9, 2004.

(19) Sjostrom L, Narbro K, Sjostrom CD, Karason K, Larsson B, Wedel H et al. Effects of bariatric surgery on mortality in Swedish obese subjects. New England Journal of Medicine 357(8):741-52, 2007.

(20) Shah M, Simha V, Garg A. Long-Term Impact of Bariatric Surgery on Body Weight, Comorbidities, and Nutritional Status. J Clin Endocrinol Metab 91(11):4223-4231, 2006.

(21) Vogel JA, Franklin BA, Zalesin KC, Trivax JE, Krause KR, Chengelis DL et al. Reduction in Predicted Coronary Heart Disease Risk After Substantial Weight Reduction After Bariatric Surgery. The American Journal of Cardiology 99(2):222-226, 2007.

(22) DeMaria EJ. Bariatric Surgery for Morbid Obesity. N Engl J Med 356(21):2176-2183, 2007.

(23) Chapman AE, Kiroff G, Game P, Foster B, O'Brien P, Ham J et al. Laparoscopic adjustable gastric banding in the treatment of obesity: a systematic literature review. Surgery 135(3):326-51, 2004.

(24) Brolin RE. Gastric bypass. Surgical Clinics of North America 81(5):1077-95, 2001.

(25) O'Brien PE, Dixon JB, Laurie C, Skinner S, Proietto J, McNeil J et al. Treatment of mild to moderate obesity with laparoscopic adjustable gastric banding or an intensive medical program: a randomized trial. Annals of Internal Medicine 144(9):625-33, 2006.

(26) Parikh MS, Fielding GA, Ren CJ. U.S. experience with 749 laparoscopic adjustable gastric bands: intermediate outcomes. Surgical Endoscopy (12):1631-1635, 2005

(27) Brolin RE. Bariatric surgery and long-term control of morbid obesity. JAMA 288(22):2793-6, 2002.

(28) Pories WJ, Swanson MS, MacDonald KG, Long SB, Morris PG, Brown BM et al. Who would have thought it? An operation proves to be the most effective therapy for adult-onset diabetes mellitus. Annals of Surgery 222(3):339-50, 1995.

(29) Hsu LK, Benotti PN, Dwyer J, Roberts SB, Saltzman E, Shikora S et al. Nonsurgical factors that influence the outcome of bariatric surgery: a review. Psychosomatic Medicine 60(3):338-46, 1998.

(30) Douketis JD, Macie C, Thabane L, Williamson DF. Systematic review of long-term weight loss studies in obese adults: clinical significance and applicability to clinical practice. Int J Obes Relat Metab Disord 29(10):1153-1167, 2005.

(31) Sarwer DB, Wadden TA, Fabricatore AN. Psychosocial and Behavioral Aspects of Bariatric Surgery. Obesity Res 13(4):639-648, 2005.

(32) Sjostrom L, Lindroos AK, Peltonen M, Torgerson J, Bouchard C, Carlsson B et al. Lifestyle, Diabetes, and Cardiovascular Risk Factors 10 Years after Bariatric Surgery. N Engl J Med 351(26):2683-2693, 2004.

(33) Kalarchian MA, Marcus MD, Wilson GT, Labouvie EW, Brolin RE, LaMarca LB. Binge eating among gastric bypass patients at long-term follow-up. Obesity Surgery 12(2):270-5, 2002.

(34) Clark MM, Balsiger BM, Sletten CD, Dahlman KL, Ames G, Williams DE et al. Psychosocial factors and 2-year outcome following bariatric surgery for weight loss. Obesity Surgery 13(5):739-45, 2003.

(35) Kinzl J, Schrattenecker M, Traweger C, Mattesich M, Fiala M, Biebl W. Psychosocial Predictors of Weight Loss after Bariatric Surgery. Obesity Surgery 16(12):1609-1614, 2006.

(36) Jakicic JM. The role of physical activity in prevention and treatment of body weight gain in adults. Journal of Nutrition 132(12):3826S-3829S, 2002.

(37) Wing RR, Hill JO. Successful weight loss maintenance. Annual Review of Nutrition 21:323-41, 2001.

(38) Jakicic JM, Clark K, Coleman E, Donnelly JE, Foreyt J, Melanson E et al. American College of Sports Medicine position stand. Appropriate intervention strategies for weight loss and prevention of weight regain for adults. Medicine & Science in Sports & Exercise 33(12):2145-56, 2001.

(39) Cook CM, Edwards C. Success habits of long-term gastric bypass patients. Obesity Surgery 9(1):80-2, 1999.

(40) Bond DS, Evans RK, Wolfe LG, Meador JG, Sugerman HJ, Kellum JM et al. Impact of self-reported physical activity participation on proportion of excess weight loss and BMI among gastric bypass surgery patients. American Surgeon 70(9):811-4, 2004.

(41) Marcus BH, Dubbert PM, Forsyth LH, McKenzie TL, Stone EJ, Dunn AL et al. Physical activity behavior change: issues in adoption and maintenance. Health Psychology (1 Suppl):32-41, 2000.

(42) Steptoe A, Rink E, Kerry S. Psychosocial predictors of changes in physical activity in overweight sedentary adults following counseling in primary care. Preventive Medicine 31(2 Pt 1):183-94, 2000.

(43) Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Medicine & Science in Sports & Exercise 32(5):963-75, 2000.

(44) Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. Medicine & Science in Sports & Exercise 34(12):1996-2001, 2002.

(45) Gallagher KI, Jakicic JM, Napolitano MA, Marcus BH. Psychosocial factors related to physical activity and weight loss in overweight women. Medicine & Science in Sports & Exercise 38(5):971-80, 2006.

(46) U.S.Department of Health and Human Serivces and U.S.department of Agriculture. Dietary Guidelines for Americans, 2005. 6th. 2005. Washington, DC: Government Printing Office. 2005.

(47) Mannucci E, De Bellis A, Cernigoi AM, Tortul C, Rotella CM, Velussi M. Further data on the comparison between World Health Organization and American Diabetes Association diagnostic criteria DIAINF Study Group. Diabetes Care 22(10):1755-7, 1999.

(48) Eckel RH, York DA, Rossner S, Hubbard V, Caterson I, St Jeor ST et al. Prevention Conference VII: Obesity, a worldwide epidemic related to heart disease and stroke: executive summary. Circulation 110(18):2968-75, 2004.

(49) McTigue K, Larson JC, Valoski A, Burke G, Kotchen J, Lewis CE et al. Mortality and Cardiac and Vascular Outcomes in Extremely Obese Women. JAMA: The Journal of the American Medical Association 296(1):79-86, 2006.

(50) Hooper MM, Stellato TA, Hallowell PT, Seitz BA, Moskowitz RW. Musculoskeletal findings in obese subjects before and after weight loss following bariatric surgery. Int J Obes 31(1):114-120, 2006.

(51) Schmitz KH, Jacobs DR, Jr., Leon AS, Schreiner PJ, Sternfeld B. Physical activity and body weight: associations over ten years in the CARDIA study. Coronary Artery Risk Development in Young Adults. International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity 24(11):1475-87, 2000.

(52) Hill JO, Wyatt HR. Role of physical activity in preventing and treating obesity. Journal of Applied Physiology 99(2):765-70, 2005.

(53) He XZM, Baker DWM. Body Mass Index, Physical Activity, and the Risk of Decline in Overall Health and Physical Functioning in Late Middle Age. American Journal of Public Health Obesity94(9):1567-1573, 2004.

(54) Kolotkin RL, Head S, Hamilton M, Tse CK. Assessing Impact of Weight on Quality of Life. Obesity Research 3(1):49-56, 1995.

(55) Brach JS, VanSwearingen JM, FitzGerald SJ, Storti KL, Kriska AM. The relationship among physical activity, obesity, and physical function in community-dwelling older women. Preventive Medicine 39(1):74-80, 2004.

(56) Alley DE, Chang VW. The Changing Relationship of Obesity and Disability, 1988-2004. JAMA: The Journal of the American Medical Association 298(17):2020-2027, 2007.

(57) Houston DK, Stevens J, Cai J, Morey MC. Role of weight history on functional limitations and disability in late adulthood: the ARIC study. Obesity Research 13(10):1793-802, 2005.

(58) Ferraro KF, Su YP, Gretebeck RJ, Black DR, Badylak SF. Body mass index and disability in adulthood: a 20-year panel study. American Journal of Public Health 92(5):834-40, 2002.

(59) Jensen GL. Obesity and functional decline: epidemiology and geriatric consequences. Clinics in Geriatric Medicine 21(4):677-87, 2005.

(60) Stenholm S, Sainio P, Rantanen T, Alanen E, Koskinen S. Effect of co-morbidity on the association of high body mass index with walking limitation among men and women aged 55 years and older. Aging-Clinical & Experimental Research (4):277-283, 2007.

(61) Mattsson E, Larsson UE, Rossner S. Is walking for exercise too exhausting for obese women? International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity 21(5):380-6, 1997.

(62) Browning RC, Kram R. Energetic cost and preferred speed of walking in obese vs. normal weight women. Obesity Research 13(5):891-9, 2005.

(63) Goodpaster BH, Kelley DE, Wing RR, Meier A, Thaete FL. Effects of weight loss on regional fat distribution and insulin sensitivity in obesity. Diabetes 48(4):839-47, 1999.

(64) Wing RR, Venditti E, Jakicic JM, Polley BA, Lang W. Lifestyle intervention in overweight individuals with a family history of diabetes. Diabetes Care 21(3):350-9, 1998.

(65) Ioannides-Demos LL, Proietto J, McNeil JJ. Pharmacotherapy for obesity.Drugs 65(10):1391-418, 2005.

(66) Fobi MA. Surgical treatment of obesity: a review. Journal of the National Medical Association 96(1):61-75, 2004.

(67) Karlsson J, Taft C, Ryden A, Sjostrom L, Sullivan M. Ten-year trends in health-related quality of life after surgical and conventional treatment for severe obesity: the SOS intervention study. International Journal of Obesity 31(8):1248-1261, 2007.

(68) Fisher BL, Schauer P. Medical and surgical options in the treatment of severe obesity. American Journal of Surgery 184(6B):9S-16S, 2002.

(69) Maggard MA, Shugarman LR, Suttorp M, Maglione M, Sugarman HJ, Livingston EH et al. Meta-analysis: surgical treatment of obesity. Annals of Internal Medicine 142(7):547-59, 2005.

(70) Crookes PF. Surgical treatment of morbid obesity. Annual Review of Medicine 57(1):243-264, 2006.

(71) Zhao Y, Encinosa W. Bariatric Surgery Utilization and Outcomes in 1998 and 2004. Statistical Brief #23. 2007. Rockville, MD, Agency for Healthcare Research and Quality.

(72) Buchwald H. Bariatric surgery for morbid obesity: Health implications for patients, health professionals, and third-party payers. Journal of the American College of Surgeons 200(4):593-604, 2005.

(73) Nadler EP, Youn HA, Ginsburg HB, Ren CJ, Fielding GA. Short-term results in 53 US obese pediatric patients treated with laparoscopic adjustable gastric banding. Journal of Pediatric Surgery 141; 42(1):137-141, 2007.

(74) Quebbemann B, Engstrom D, Siegfried T, Garner K, Dallal R. Bariatric surgery in patients older than 65 years is safe and effective. Surgery for Obesity & Related Diseases 392; 1(4):389-392, 2005.

(75) Olbers T, Lonroth H, Fagevik-Olsen M, Lundell L. Laparoscopic gastric bypass: development of technique, respiratory function, and long-term outcome. Obesity Surgery 13(3):364-70, 2003.

(76) Papasavas PK, Hayetian FD, Caushaj PF, Landreneau RJ, Maurer J, Keenan RJ et al. Outcome analysis of laparoscopic Roux-en-Y gastric bypass for morbid obesity. The first 116 cases. Surgical Endoscopy 16(12):1653-7, 2002.

(77) Suter M, Giusti V, Heraief E, Zysset F, Calmes JM. Laparoscopic Roux-en-Y gastric bypass: initial 2-year experience. Surgical Endoscopy 17(4):603-9, 2003.

(78) Metropolitan Life Insurance Co. New weight standards for men and women. Stat Bull Metrop Life Insur Co 1959; 40:1-4.

(79) Biertho L, Steffen R, Ricklin T, Horber FF, Pomp A, Inabnet WB et al. Laparoscopic gastric bypass versus laparoscopic adjustable gastric banding: a comparative study of 1,200 cases. Journal of the American College of Surgeons 197(4):536-44, 2003.

(80) Andrew CG, Hanna W, Look D, McLean AP, Christou NV. Early results after laparoscopic Roux-en-Y gastric bypass: effect of the learning curve. Canadian Journal of Surgery 49(6):417-21, 2006.

(81) Bult MJF, van Dalen T, Muller AF. Surgical treatment of obesity. Eur J Endocrinol 2008; 158(2):135-145.

(82) Mason EE, Renquist KE, Huang YH, Jamal M, Samuel I. Causes of 30-day bariatric surgery mortality: with emphasis on bypass obstruction. Obesity Surgery 17(1):9-14, 2007.

(83) varez-Leite JI. Nutrient deficiencies secondary to bariatric surgery. Current Opinion in Clinical Nutrition & Metabolic Care 7(5):569-575, 2004.

(84) Christou NV, Sampalis JS, Liberman M, Look D, Auger S, McLean AP et al. Surgery decreases long-term mortality, morbidity, and health care use in morbidly obese patients. Annals of Surgery 240(3):416-23, 2004.

(85) Flum DR, Dellinger EP. Impact of gastric bypass operation on survival: a population-based analysis. Journal of the American College of Surgeons 199(4):543-551, 2004.

(86) Adams TD, Gress RE, Smith SC, Halverson RC, Simper SC, Rosamond WD et al. Long-term mortality after gastric bypass surgery. New England Journal of Medicine 357(8):753-61, 2007.

(87) Sjostrom CD, Lissner L, Wedel H, Sjostrom L. Reduction in incidence of diabetes, hypertension and lipid disturbances after intentional weight loss induced by bariatric surgery: the SOS Intervention Study. Obesity Research 7(5):477-84, 1999.

(88) Sjostrom CD, Peltonen M, Wedel H, Sjostrom L. Differentiated long-term effects of intentional weight loss on diabetes and hypertension. Hypertension 36(1):20-5, 2000.

(89) Dixon JB, O'Brien PE, Playfair J, Chapman L, Schachter LM, Skinner S et al. Adjustable Gastric Banding and Conventional Therapy for Type 2 Diabetes: A Randomized Controlled Trial. JAMA: The Journal of the American Medical Association 299(3):316-323, 2008.

(90) Buchwald H, Estok R, Fahrbach K, Banel D, Jensen MD, Pories WJ et al. Weight and Type 2 Diabetes after Bariatric Surgery: Systematic Review and Meta-analysis. The American Journal of Medicine 122(3):248-256, 2009.

(91) Peltonen M, Lindroos AK, Torgerson JS. Musculoskeletal pain in the obese: a comparison with a general population and long-term changes after conventional and surgical obesity treatment. Pain 104(3):549-57, 2003.

(92) Melissas J, Kontakis G, Volakakis E, Tsepetis T, Alegakis A, Hadjipavlou A. The effect of surgical weight reduction on functional status in morbidly obese patients with low back pain. Obesity Surgery 15(3):378-381, 2005.

(93) Christou NV, Look D, MacLean LD. Weight gain after short- and long-limb gastric bypass in patients followed for longer than 10 years. Annals of Surgery 244(5):734-40, 2006.

(94) Das SK, Roberts SB, McCrory MA, Hsu LK, Shikora SA, Kehayias JJ et al. Long-term changes in energy expenditure and body composition after massive weight loss induced by gastric bypass surgery. American Journal of Clinical Nutrition 78(1):22-30, 2003.

(95) Belle SH, Berk PD, Courcoulas AP, Flum DR, Miles CW, Mitchell JE et al. Safety and efficacy of bariatric surgery: Longitudinal Assessment of Bariatric Surgery. Surgery for Obesity & Related Diseases 3(2):116-26, 2007.

(96) Racette SB, Deusinger SS, Deusinger RH. Obesity: overview of prevalence, etiology, and treatment. Physical Therapy 83(3):276-88, 2003.

(97) Jakicic JM. Exercise in the treatment of obesity. Endocrinology & Metabolism Clinics of North America 32(4):967-80, 2003.

(98) Jakicic JM, Wing RR, Winters-Hart C. Relationship of physical activity to eating behaviors and weight loss in women. Medicine & Science in Sports & Exercise 34(10):1653-9, 2002.

(99) US Dept of Health and Human services, Centers for Disease Control and Prevention. Physical Activity and Health: A report of the Surgron General. National Center for Chronic Disease Prevention and Health Promotion . 1996.

(100) Brandenburg D, Kotlowski R. Practice makes perfect? Patient response to a prebariatric surgery behavior modification program. Obesity Surgery 15(1):125-32, 2005.

(101) Boan J, Kolotkin RL, Westman EC, McMahon RL, Grant JP. Binge eating, quality of life and physical activity improve after Roux-en-Y gastric bypass for morbid obesity. Obesity Surgery 14(3):341-8, 2004.

(102) Schoeller DA, Shay K, Kushner RF. How much physical activity is needed to minimize weight gain in previously obese women? American Journal of Clinical Nutrition 66(3):551-6, 1997.

(103) Fogelholm M, Kukkonen-Harjula K, Nenonen A, Pasanen M. Effects of walking training on weight maintenance after a very-low-energy diet in premenopausal obese women: a randomized controlled trial. Archives of Internal Medicine 160(14):2177-84, 2000.

(104) Rissanen AM, Heliovaara M, Knekt P, Reunanen A, Aromaa A. Determinants of weight gain and overweight in adult Finns. European Journal of Clinical Nutrition 45(9):419-30, 1991.

(105) Klem ML, Wing RR, McGuire MT, Seagle HM, Hill JO. A descriptive study of individuals successful at long-term maintenance of substantial weight loss. American Journal of Clinical Nutrition 66(2):239-46, 1997.

(106) Jakicic JM, Marcus BH, Gallagher KI, Napolitano M, Lang W. Effect of exercise duration and intensity on weight loss in overweight, sedentary women: a randomized trial. JAMA 290(10):1323-30, 2003.

(107) Jeffery RW, Wing RR, Sherwood NE, Tate DF. Physical activity and weight loss: does prescribing higher physical activity goals improve outcome? American Journal of Clinical Nutrition 78(4):684-9, 2003.

(108) Evans RK, Bond DS, Demaria EJ, Wolfe LG, Meador JG, Kellum JM. Initiation and progression of physical activity after laparoscopic and open gastric bypass surgery. Surgical Innovation 11(4):235-9, 2004.

(109) Klem ML, Wing RR, Chang CC, Lang W, McGuire MT, Sugerman HJ et al. A case-control study of successful maintenance of a substantial weight loss: individuals who lost weight through surgery versus those who lost weight through non-surgical means. International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity 24(5):573-9, 2000.

(110) Lichtman SW, Pisarska K, Berman ER, Pestone M, Dowling H, Offenbacher E et al. Discrepancy between self-reported and actual caloric intake and exercise in obese subjects. New England Journal of Medicine 327(27):1893-8, 1992.

(111) King AC, Blair SN, Bild DE, Dishman RK, Dubbert PM, Marcus BH et al. Determinants of physical activity and interventions in adults. Medicine & Science in Sports & Exercise 24(6 Suppl):S221-36, 1992.

(112) Ekkekakis P, Lind E. Exercise does not feel the same when you are overweight: the impact of self-selected and imposed intensity on affect and exertion. International Journal of Obesity 30(4):652-660, 2006.

(113) Brownson RC, Jones DA, Pratt M, Blanton C, Heath GW. Measuring physical activity with the behavioral risk factor surveillance system. Medicine & Science in Sports & Exercise 32(11):1913-8, 2000.

(114) King AC. Intervention strategies and determinants of physical activity and exercise behavior in adult and older adult men and women. World Review of Nutrition & Dietetics 82:148-58, 1997.

(115) Booth ML, Owen N, Bauman A, Clavisi O, Leslie E. Social-cognitive and perceived environment influences associated with physical activity in older Australians. Preventive Medicine 31(1):15-22, 2000.

(116) Sternfeld B, Ainsworth BE, Quesenberry CP. Physical activity patterns in a diverse population of women. Preventive Medicine 28(3):313-23, 1999.

(117) Bandura A. Self-efficacy: toward a unifying theory of behavioral change. Psychological Review 84(2):191-215, 1977.

(118) Oman RF, King AC. Predicting the adoption and maintenance of exercise participation using self-efficacy and previous exercise participation rates. American Journal of Health Promotion 12(3):154-61, 1998.

(119) Manson JE, Skerrett PJ, Greenland P, VanItallie TB. The escalating pandemics of obesity and sedentary lifestyle. A call to action for clinicians. Archives of Internal Medicine 164(3):249-58, 2004.

(120) King AC, Castro C, Wilcox S, Eyler AA, Sallis JF, Brownson RC. Personal and environmental factors associated with physical inactivity among different racial-ethnic groups of U.S. middle-aged and older-aged women. Health Psychology (4):354-364, 2000.

(121) Bond DS, Evans RK, Demaria EJ, Wolfe LG, Meador JG, Kellum JM et al. Physical activity stage of readiness predicts moderate-vigorous physical activity participation among morbidly obese gastric bypass surgery candidates. Surgery for Obesity & Related Diseases 2(2):128-32, 2006.

(122) Wade DT, Collin C. The Barthel ADL Index: a standard measure of physical disability?. International Disability Studies 10(2):64-7, 1988.

(123) St Onge M, Mignault D, Allison DB, Rabasa-Lhoret R. Evaluation of a portable device to measure daily energy expenditure in free-living adults. American Journal of Clinical Nutrition 85(3):742-9, 2007.

(124) Jakicic JM, Marcus M, Gallagher KI, Randall C, Thomas E, Goss FL et al. Evaluation of the SenseWear Pro Armband to assess energy expenditure during exercise. Medicine & Science in Sports & Exercise 36(5):897-904, 2004.

(125) Ware JE, Jr., Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Medical Care 30(6):473-83, 1992.

(126) Ware JE, Jr. Standards for validating health measures: definition and content. Journal of Chronic Diseases 40(6):473-80, 1987.

(127) McHorney CA, Ware JE, Jr., Raczek AE. The MOS 36-Item Short-Form Health Survey (SF-36): II. Psychometric and clinical tests of validity in measuring physical and mental health constructs. Medical Care 31(3):247-63, 1993.

(128) Temple PC, Travis B, Sachs L, Strasser S, Choban P, Flancbaum L. Functioning and well-being of patients before and after elective surgical procedures. Journal of the American College of Surgeons 181(1):17-25, 1995.

(129) Choban PS, Onyejekwe J, Burge JC, Flancbaum L. A health status assessment of the impact of weight loss following Roux-en-Y gastric bypass for clinically severe obesity. Journal of the American College of Surgeons 188(5):491-7, 1999.

(130) Marcus BH, Selby VC, Niaura RS, Rossi JS. Self-efficacy and the stages of exercise behavior change. Research Quarterly for Exercise & Sport 63(1):60-6, 1992.

(131) Steinhardt MA, Dishman RK. Reliability and validity of expected outcomes and barriers for habitual physical activity. Journal of Occupational Medicine 31(6):536-46, 1989.

(132) Josbeno DA, Jakicic JM, Hergenroeder A, Eid GM. Physical activity and physical function changes in obese individuals after gastric bypass surgery. Surgery for Obesity and Related Diseases In Press, Corrected Proof.

(133) Sallis JF, Saelens BE. Assessment of physical activity by self-report: status, limitations, and future directions. Research Quarterly for Exercise & Sport 71(2 Suppl):S1-14, 2000.

(134) Donnelly JEEd, Blair SNP, Jakicic JMP, Manore MMP, Rankin JWP, Smith BKP. Appropriate Physical Activity Intervention Strategies for Weight Loss and Prevention of Weight Regain for Adults. Medicine & Science in Sports & Exercise 41(2):459-471, 2009.

(135) Davis JD, Engel CC, Mishkind M, Jaffer A, Sjoberg T, Tinker T et al. Provider and patient perspectives regarding health care for war-related health concerns. Patient Education and Counseling 68(1):52-60, 2007.

(136) Evans RK, Bond DS, Wolfe LG, Meador JG, Herrick JE, Kellum JM et al. Participation in 150 min/wk of moderate or higher intensity physical activity yields greater weight loss after gastric bypass surgery. Surgery for Obesity & Related Diseases 3(5):526-30, 2007.

(137) Jakicic JM, Marcus BH, Lang W, Janney C. Effect of exercise on 24-month weight loss maintenance in overweight women. Archives of Internal Medicine 168(14):1550-9, 2008.

(138) Ewbank PP, Darga LL, Lucas CP. Physical activity as a predictor of weight maintenance in previously obese subjects. Obesity Research 3(3):257-63, 1995.

(139) Brach JS, VanSwearingen JM, Newman AB, Kriska AM. Identifying early decline of physical function in community-dwelling older women: performance-based and self-report measures. Physical Therapy 82(4):320-8, 2002.

(140) Morey MC, Sloane R, Pieper CF, Peterson MJ, Pearson MP, Ekelund CC et al. Effect of physical activity guidelines on physical function in older adults. Journal of the American Geriatrics Society 56(10):1873-8, 2008.

(141) Simonsick EM, Guralnik JM, Fried LP. Who walks? Factors associated with walking behavior in disabled older women with and without self-reported walking difficulty. Journal of the American Geriatrics Society 47(6):672-80, 1999.

(142) Sternfeld B, Ngo L, Satariano WA, Tager IB. Associations of body composition with physical performance and self-reported functional limitation in elderly men and women. American Journal of Epidemiology 156(2):110-21, 2002.

(143) Visser M, Simonsick EM, Colbert LH, Brach J, Rubin SM, Kritchevsky SB et al. Type and intensity of activity and risk of mobility limitation: the mediating role of muscle parameters. Journal of the American Geriatrics Society 53(5):762-70, 2005.

(144) Koster A, Penninx BWJH, Newman AB, Visser M, van Gool CH, Harris TB et al. Lifestyle Factors and Incident Mobility Limitation in Obese and Non-obese Older Adults. Obesity Res 15(12):3122-3132, 2007.

(145) Frezza EE, Shebani KO, Wachtel MS. Laparoscopic Gastric Bypass for Morbid Obesity Decreases Bodily Pain, Improves Physical Functioning, and Mental and General Health in Women. Journal of Laparoendoscopic & Advanced Surgical Techniques 17(4):440-447, 2007.

(146) Miller GD, Nicklas BJ, You T, Fernandez A. Physical function improvements after laparoscopic Roux-en-Y gastric bypass surgery. Surgery for Obesity and Related Diseases In Press, Corrected Proof.

(147) Miller GD, Nicklas BJ, Davis C, Loeser RF, Lenchik L, Messier SP. Intensive weight loss program improves physical function in older obese adults with knee osteoarthritis. Obesity 14(7):1219-30, 2006.

(148) Dymek MP, Le Grange D, Neven K, Alverdy J. Quality of life after gastric bypass surgery: a cross-sectional study. Obesity Research 10(11):1135-42, 2002.