THE 12-WEEK EFFECT OF CHANGE IN BODY WEIGHT AND BODY COMPOSITION ON MUSCULAR STRENGTH AND FUNCTION IN OVERWEIGHT ADULTS

By

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PURPOSE: The purpose of this study is to examine the relationship between the changes in body weight and lean body mass with changes in muscular strength and function in overweight and obese adults before and after a 12 week weight loss intervention. **METHODS:** Fifty-seven overweight adults (42.4 ± 3.8 % body fat) participated in this study. Forty eight subjects completed the 12 week weight loss intervention consisting of weekly behavioral counseling and the use of the HealthWear™ System, a computer-based monitoring system that objectively measures energy expenditure. Before and after this 12 week intervention, body weight, body mass index (BMI), body composition, muscular strength (1-RM chest press, 1-RM leg extension, grip strength), and function (sit-to-stand) were measured. **RESULTS:** Paired sample T-tests revealed a significant decrease in body weight, lean body mass, 1-RM chest press, and 1-RM leg extension and a significant increase in function from baseline to week 12 (Table 1). There was no significant change in grip strength from baseline to week 12. Correlation analyses revealed a moderate negative correlation between the percent change in body weight and the change in function (r = -.352).

Table 1.

	Baseline	12 Weeks	Change	p-value
Weight (kg)	88.4 ± 9.1	83.2 ± 9.6	-5.2 ± 3.4	<.001
LBM (kg)	50.9 ± 4.9	50.1 ± 4.7	-0.8 ± 1.7	0.002
1-RM chest (kg)	27.65 ± 6.7	25.35 ± 6.4	-2.3 ± 4.2	0.003
1-RM leg (kg)	35.9 ± 11.8	30.9 ± 10.1	-4.9 ± 11.4	<0.001
Grip Strength (kg)	32.1 ± 6.3	31.6 ± 6.6	-0.5 ± 6.4	0.36
Sit-to-Stand	14.5 ± 3.4	15.6 ± 4.6	1.1 ± 3.8	0.05

CONCLUSION: Although LBM and strength decreased during this 12 week intervention, weight loss produced a marked improvement in function. This is an important finding because function can improve during weight loss regardless of resistance training. Improved function can potentially create a higher quality of life and longer independent living in individuals who lose approximately 6% of their total body weight.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

1.0 Introduction

A significant public health problem in the United States is related to excess body weight. It is estimated that in excess of 60 percent of adults in the United States are overweight, which is defined as a body mass index (BMI) of a least 25 kg/m^2 (Flegal et al, 1998). Moreover, in excess of 30 percent of adults are classified as obese (BMI $\geq$ 30 kg/m^2). These percentages have risen significantly over the past few decades (Kuczmarski, Flegal, Campbell, & Johnson, 1994), despite the addition of surgical, pharmacotherapy, and enhanced behavioral interventions to address this health concern.

Excess amounts of weight can contribute to health complications that increase mortality. It is estimated that overweight and obesity contribute to approximately 325,000 deaths per year (Allison et al, 1999). In addition, obesity increases the risk of various chronic diseases such as heart disease, diabetes, and cancer (Rimm et al, 1995; Wing et al, 1999), which may be a result of increases in risk factors such as hypertension, hyperlipidemia, and insulin resistance. Recent data indicates that the direct cost of treating these obesity-related conditions in the United States has been estimated to be $70 billion, or 7% of health care expenditures, while indirect costs are estimated to be $48 billion (Colditz, 1999). These health care costs may actually be an underestimation of the actual cost because the impact of reduced physical functioning is not considered in the estimate (Coakley et al, 1998). These factors support the need to develop effective interventions to address the public health implications of obesity.

Effective interventions for weight loss are focused on creating an energy deficit, with the most effective behavioral interventions combining a reduction in energy intake (diet) with an increase in energy expenditure (physical activity) (Wing, 2001). It has been demonstrated that behavioral interventions which combine these two components typically result in weight loss of approximately 10 percent of initial body weight over a 5 to 6 month period (Wing, 1998), and this can significantly improve health-related outcomes (Agurs-Collins et al, 1997; Wing et al, 1987; & Torjeson et al, 1997). However, it appears that loss of lean body mass contributes 10 to 47 percent of the total weight loss typically observed with behavioral interventions (Ross et al, 1996; Trombetta et al, 2003; Bryner et al, 1999; Byrne et al, 2003; & Lynch et al, 2000).

There is a body of literature which demonstrated the potential negative influence of the reductions in lean body mass on physiological and metabolic factors that may impact initial weight loss and long-term weight loss maintenance. A primary focus of research has been on the potential contribution of the loss of lean body mass on the reductions in resting energy expenditure typically observed with weight loss (Ross et al, 1996; Trombetta et al, 2003; Bryner et al, 1999; Byrne et al, 2003; Donnelly et al, 1991; Lynch et al, 2000). It has been demonstrated that resting energy expenditure is correlated with absolute level of lean body mass (Ross et al, 1996; Byrne et al, 2003; & Bryner et al, 1999). This has lead to some evidence that the reductions in lean body mass that may occur with weight loss at least partially contributes to the concurrent reduction in resting energy expenditure that is typically observed (Ross et al, 1996; Trombetta et al, 2003; Bryner et al, 1999; Byrne et al, 2003; Donnelly et al, 1991). There is also evidence that the quality of the lean body mass may contribute to metabolic pathways that contribute to glucose control, insulin sensitivity, and other parameters that may impact body weight regulation. This has partially contributed to a line of research focusing on potential interventions, such as resistance exercise, to minimize the loss of lean body mass and the concurrent physiological and metabolic factors that my impact body weight regulation (Ross et al, 1996; Ryan et al, 1995; Schmitz et al, 2002; Ballor et al, 1988; Bryner et al, 1999).

Despite the potential physiological and metabolic benefits of maintaining the amount and/or quality of lean body mass with weight loss, there may be additional outcomes impacted by the change in lean body mass typically observed with weight loss. It is widely believed that amount of lean body mass is positively correlated with muscular strength (Kraemer et al, 1999), and that increases in lean body mass resulting from restistance exercise will result in an increase in muscular strength. However, an understudied area is whether the loss of lean body mass with weight loss results in a concurrent reduction in muscular strength, and whether the loss of lean mass further contributes to potential changes in functional ability of overweight and obese adults. Moreover, it is unclear if observed changes in these variables are associated with perceived ability to perform common activities of daily living (ADL) or changes in perceived function according to life quality outcomes. This study will focus on documenting the observed and perceived changes in function that occur with weight loss, and will further examine the potential contribution change in lean body mass on these outcomes.

1.1. Rationale and Significance

Several studies have shown that lean body mass is compromised during weight loss interventions (Ross et al, 1996; Kraemer et al, 1999). This decline in lean body mass may impact absolute and relative (based on body weight) measures of muscular strength. It has been found that subjects participating in weight loss regimens with combined diet and endurance exercise activities lose approximately 6% of their initial strength (Donnelly et al, 1991). Additional research in the geriatric population has warranted that muscle strength has been shown to correlate with overall functional performance as well as with performance at specific activities such as attaining a standing position, walking, and climbing stairs (Bohannon, 1992, and Hughes et al, 1996). If function is compromised due to a loss of lean body mass and strength during weight loss regimens, it would support the need for resistance exercise training to be incorporated into these weight loss interventions. Resistance training may not only be incorporated to spare the metabolic effects of lean body mass, but to maintain or increase the functional performance related to lean body mass and strength.

1.2. Specific Aims

<u>Primary Specific Aims</u>

1. To examine the relationship between the change in body weight and the change in muscular strength in overweight and obese individuals.
2. To examine the relationship between the change in lean body mass and the change in muscular strength in overweight and obese individuals.
3. To examine the relationship between the change in body weight and the change in functional ability in overweight and obese individuals.
4. To examine the relationship between the change in lean body mass and the change in functional ability in overweight and obese individuals.
5. To examine the relationship between the change in strength and the change in functional ability in overweight and obese individuals.
6. To examine the relationship between the change in leisure time physical activity and the change in functional ability in overweight and obese individuals.

<u>Secondary Specific Aims</u>

7. To examine the effect of a 12-week weight loss program on absolute and relative changes in body weight in overweight and obese adults.
8. To examine the effect of a 12-week weight loss program on absolute and relative changes in lean body mass in overweight and obese adults.
9. To examine the effect of a 12-week weight loss program on absolute and relative changes in muscular strength in overweight and obese adults.

10. To examine the effect of a 12-week weight loss program on changes in functional ability in overweight and obese adults.

1.3. Research Hypotheses

Primary Research Hypotheses

1. It is hypothesized that there will be a significant correlation between change in body weight and change in muscular strength in overweight and obese individuals.
2. It is hypothesized that there will be a significant correlation between change in lean body mass and change in muscular strength in overweight and obese individuals.
3. It is hypothesized that there will be a significant correlation between change in body weight and change in functional ability in overweight and obese individuals.
4. It is hypothesized that there will be a significant correlation between change in lean body mass and change in functional ability in overweight and obese individuals.
5. It is hypothesized that there will be a significant correlation between the change in strength and the change in functional ability in overweight and obese individuals.
6. It is hypothesized that there will be a significant correlation between change in leisure time physical activity and change in functional ability in overweight and obese individuals.

Secondary Research Hypotheses

7. It is hypothesized that there will be absolute and relative changes in body weight in overweight and obese adults after a 12-week weight loss program.
8. It is hypothesized that there will be absolute and relative changes in lean body mass in overweight and obese adults after a 12-week weight loss program.
9. It is hypothesized that there will be absolute and relative changes in muscular strength in overweight and obese adults after a 12-week weight loss program.

10. It is hypothesized that there will be changes in functional ability in overweight and obese adults after a 12-week weight loss program.

II. LITERATURE REVIEW

2.1. Obesity Prevalence

A significant public health problem in the United States is related to excess body weight. Currently, approximately 60 million U.S. adults are overweight. Moreover, in excess of 30 percent of adults are classified as obese (BMI $\geq$30 kg/m^2). These percentages have risen significantly over the past few decades (Kuczmarski, Flegal, Campbell, & Johnson, 1994) despite the addition of surgical, pharmacotherapy, and enhanced behavioral interventions to address this health concern.

2.2. Risks Associated with Obesity

Overweight and obese individuals may display several risk factors of CHD such as hypertension, hyperlipidemia, and diabetes mellitus. Furthermore, obesity has been linked to other serious health problems such as musculoskeletal disorders and cancer (Tsai et al.). Since obesity is a demonstrated health risk factor for both men and women, it is a risk factor to be avoided. Arthur Leon (1987) suggests that it is a factor that is easier to avoid then to treat. Therefore, fat weight gain should be monitored and controlled before it develops into unmanageable obesity. One way of controlling or preventing body fat gain has been through exercise intervention. Exercise training programs have been effective in reducing percent body fat because they increase the individual's weekly kilocalorie output above previously sedentary levels. Thus, the purpose of this literature review will be to examine the effectiveness of weight loss interventions and to further examine their effect on muscle mass, muscle strength, and functional performance.

2.3. Behavioral Weight Loss Interventions

Effective interventions for weight loss are focused on creating an energy deficit, with the most effective behavioral interventions combining a reduction in energy intake (diet) with an increase in energy expenditure (physical activity). Hagan et al. (1986) compared diet, exercise, and diet-plus-exercise in men and women for 12 weeks. Their results support the incorporation of both diet and exercise in treatment programs and suggest that little change in body weight can be expected from exercise alone during a short-term intervention. In addition, Wood et al. (1991) reported significantly greater weight loss following a 1-year intervention in men participating in a diet-plus-exercise intervention compared with those receiving only a diet intervention (8.7 kg ± 5.7 kg versus 5.1 kg ± 5.8 kg). Furthermore, in a study conducted by Wing et al. (1988), she reported significantly greater weight loss in a diet-plus-exercise intervention compared with a diet intervention alone. After an additional year of less intensive intervention, the diet-plus-exercise group maintained an average weight loss of 7.9 kg versus 3.8 kg in the diet-only group.

2.4. Effects of Weight Loss on LBM

However, there is some concern that a significant portion of this weight loss may be in the form of lean body mass. Ross et al. (2000) studied 52 obese men who were randomly assigned to one of four study groups: diet-induced weight loss, exercise-induced weight loss, exercise without weight loss, and control. After 20 weeks, Ross et al. found that skeletal muscle mass decreased by 5% (23% of total weight lost) in the diet-induced weight loss group but was unchanged in both exercise groups.

In addition, Trombetta et al. (2003) studied the effects of a 4 month hypocaloric diet and a hypocaloric diet with exercise training (aerobic plus resistance training) on several different parameters in 59 obese women. Trombetta found that in the diet group, lean body mass was reduced by 10% (47.19% of total weight lost) whereas the diet plus exercise group only saw a 3% reduction in lean body mass (13.2% of total weight lost), which was not statistically significant.

Because of observed reductions in lean body mass, research has focused on the potential influence of these changes on physiological factors that may impact initial weight loss and the long-term weight management. There is a significant body of literature which demonstrates a relationship between lean body mass and resting energy expenditure (Ross et al; Wadden et al; Byrne et al; &

Bryner et al), along with a body of literature which demonstrates that both lean body mass and resting energy expenditure decrease with weight loss (Ross et al; Trombetta et al; Bryner et al; Byrne et al; Donnelly et al; & Lynch et al). This has partially contributed to research focusing on potential interventions, such as resistance exercise, to minimize the loss of lean body mass and concurrent reductions observed in resting energy expenditure (Ross et al; Schmitz et al; Ballor et al; Ryan et al; & Bryner et al). Although resting energy expenditure is an important factor in weight loss, the purpose of this review will focus on the effects of LBM on function.

Ross et al. (2000) found that diet-plus-exercise (aerobic exercise) did not preserve lean body mass and resting energy expenditure in a 12 week weight loss intervention study. Thus, it may be necessary to incorporate a resistance training program into a weight loss intervention to minimize the reduction in lean body mass and resting metabolic rate. This area of research however has had several different results and not all trials support this hypothesis.

For example, Donnelly et al. (1991) studied 69 females for 90 days on a very low calorie diet. Each of these subjects was assigned to one of the following groups: diet only (C), diet plus endurance training (EE), diet plus weight training (WT), or diet plus endurance exercise and weight training (EEWT). Donnelly found that changes in body weight, percent fat, fat weight, and fat-free mass were not different between groups. Declines in resting metabolic rate (RMR) were approximately 7% to approximately 12% of baseline values with no differences among groups. Strength index showed declines of approximately 6% for C and EE and gains of approximately 3% and approximately 10% for EEWT and WT, respectively. This clinical trial did not show advantages of any exercise regimen over diet alone for weight loss, body-composition changes, or declines in RMR.

On the other hand, Donnelly et a.l (1993) conducted a study to determine whether muscle hypertrophy is possible during a large-scale weight loss intervention. Fourteen obese females received a 3360 kJ/day liquid diet for 90 days. Seven subjects received a weight training (WT) regimen and seven subjects remained sedentary (C). Biopsy samples were obtained from the vastus lateralis muscle at baseline and after 90 days of treatment. The average weight loss over the 90 day period was 16 kg with approximately 24% of the weight loss from FFM and 76% from fat. The amount and composition of the weight loss did not differ between the WT and C groups. The cross-sectional area of the slow twitch and fast twitch fibers was unchanged by treatment in C subjects but significantly increased with WT subjects. Thus, it appears that even though FFM may be compromised, weight training can produce hypertrophy in skeletal muscle during severe energy restriction and large-scale weight loss.

Furthermore, Bryner et al. (1999) studied twenty subjects (17 women, 3 men), mean age 38 years, over 12 weeks. These subjects were randomly assigned to either a standard treatment control plus diet, or resistance exercise plus diet. The control plus diet group exercised for one hour four times/week by walking, biking, or stair climbing, whereas the resistance exercise plus diet group performed resistance training 3 days/week in the form of a circuit. Both groups consumed 800 kcal/day in the form of a liquid diet. At the end of the 12 weeks, it was found that the control plus diet group lost 4 kg of lean body mass (22% of total weight lost) whereas the resistance exercise plus diet group only lost .8 kg of lean body mass (5.5% of total weight lost) which was not statistically significant.

Keim et al. (1990) examined the effects of exercise training and the influence of a moderate calorie restriction on the training response in ten overweight women over a 14 week period. After a 2 week stabilization period, in which diets were designed to maintain body weight (BW), five women were assigned to a 12 week experimental program of diet and exercise (D+EX) that included a 50% reduction in energy intake and a program of moderate intensity aerobic exercise 6 days/week. The other five women were assigned to the same daily exercise (EX) and continued to consume the stabilization diet. Periodic measurements of resting metabolic rate (RMR), thermic effect of food (TEF), energy cost of exercise, and predicted maximal aerobic capacity were obtained. Body composition was monitored weekly. Tests of strength and anaerobic capacity were conducted. D+EX lost an average of approximately 1.1 kg of body weight per week, which was 67% fat and 33% lean weight. EX lost approximately 0.5 kg/wk, which was 86% fat and 14% lean. The RMR declined 9% in the D+EX group, whereas it was maintained in the EX group.

2.5. Effect of Weight Loss on Muscular Strength

In addition to the loss of LBM and a reduction in RMR during weight loss regimens, Donnelly has also found that subjects participating in regimens with combined diet and endurance exercise activities lose approximately 6% of their initial strength (Donnelly, 1994). It is important to determine the effect of this absolute and/or relative strength loss on the change of functional performance, both measured and perceived, to observe changes in the ability to perform activities of daily living.

Pronk et al. (1992) determined strength changes induced by very low-calorie diet (VLCD, 520 kcal/day) alone and in combination with exercise in 109 severely obese females (46.8 +/- 4.69% fat). Experimental treatments included VLCD alone, VLCD with endurance exercise (EE), VLCD with endurance exercise and resistance strength training (EERST), and VLCD with resistance strength training (RST). All subjects participated in the study for 90 days while EE, EERST, and RST exercised 4 times/week according to specified schedules. Results indicated significant differences for the change scores (baseline to 90 days) for bench press, knee flexion, upper body and lower body composite strength scores between RST and all the other groups. RST was the only treatment group that increased upper and lower body strength. No differences between groups were found for body mass losses, decrease in percent fat and fat mass. In contrast, these variables showed significant change scores for all groups. Decreases in fat-free mass (FFM) were 5.18 +/- 3.4 kg, 4.79 +/- 4.15 kg, 4.64 +/- 4.23 kg, and 3.26 +/- 2.67 kg for EE, LC, RST, and EERST, respectively. These data suggest that the combination of resistance strength training and VLCD increases strength despite a loss of FFM. However, endurance exercise and VLCD do not seem to affect body mass loss or FFM loss per se. Moreover, it seems that these increases in strength may represent a training effect which might imply improved central neuromuscular function rather than muscular hypertrophy since FFM decreased in all groups.

It is important to determine whether this strength loss is due to absolute changes in strength or relative changes in strength. If absolute strength is compromised during a weight loss intervention, the participant may still be able to maintain and/or improve function if the ratio between weight lost and strength lost is high. However, if the participant loses strength relative to body weight, this could impede upon the participant's functional performance.

2.6. Effect of Weight Loss on Functional Performance

A related area of research that is understudied is the potential impact of loss of body weight, lean body mass, and muscular strength on functional ability and functional performance in overweight and obese individuals. Moreover, it is unclear if observed changes in these variables are associated with perceived ability to perform common activities of daily living (ADL) or changes in health-related quality of life (HRQL).

Since the effect of weight loss on functional performance has been understudied in the overweight and obese population, it is imperative to look at a population in which functional performance has been studied; the elderly population. One of the primary consequences of aging, a consequence which leads to significantly impaired function in the elderly population, is the loss of skeletal muscle strength and mass. Both of these decrease up to one-third in humans between the ages of 30 and 80 years (Barton-Davis et al, 1998).

Aging typically leads to an increase in body fat and a decrease in lean body mass (LBM). Alterations in muscle mass can reflect other changes such as a decrease in strength, functional ability, and resting metabolic rate. Maintaining a balance between fat and muscle mass throughout life is crucial because the loss of muscle mass is implicated in variables of metabolic rate and physical activity and increases in body fat are associated with type II diabetes, hypertension, certain cancers, and coronary artery disease (Rogers et al, 1993). Muscle mass leads to a reduction in muscle function; therefore, muscle mass should be maintained throughout life to maintain function (Kirkendall, 1998).

Harris (1997) suggests that in relatively sedentary populations, such as the elderly, a major determinant of muscle mass is body weight. Furthermore, Forbes (1987) suggests that lean mass is logarithmically related to body fat. Thus, heavier individuals have greater lean mass, and because strength is related to mass, heavier individuals of all ages are also generally stronger when asked to perform simple tests of muscle strength. Viitasalo et al. (1985) demonstrated this using random samples of Finnish men drawn from three age groups: 31-35, 51-55 and 71-75 years of age. Although the older men had poorer isometric knee extension strength at each weight, within each age group, the heavier men had greater strength.

In addition, it has been found that changes in body size will influence muscle mass, just as it influences levels of fat and bone. In a longitudinal study of change in urinary creatinine in 260 men aged 60 years or older from the Baltimore Longitudinal Study on Aging, those men who were heavier initially had greater baseline muscle mass. Over time, the entire group lost weight. Urinary creatinine declined with weight loss and was relatively constant across weight tertiles, suggesting that weight history will affect level of muscle mass as well as current weight (Muller et al. 1995). Lastly, despite the association with greater strength, heavier body weight is associated with poorer functional health status (Launer et al. 1994), suggesting that the relationship of muscle to function may not be linear.

In a study conducted by Sami Al-Abdulwahab (1998), he found that muscle strength and functional ability remained unchanged in the 20- and 30-year-old age groups. Around the age of 40, muscle strength and functional ability began to gradually decline. Stair-climbing, timed up-and-go and balance tests in the second decade were 4 $\pm$ 1 sec, 8 $\pm$ 2 sec, and 130 $\pm$ 20 sec, respectively, against 15 $\pm$ 4 sec, 26 $\pm$ 7 sec, and 15 $\pm$ 5 sec in the eighth decade. Statistical tests showed that muscle strength and functional ability displayed a significant relationship ($p<0.001$).

If in fact LBM and strength are compromised during weight loss, additional research is warranted to determine the effect of these decrements on functional performance and the health related quality of life (HRQL). According to Fontaine et al. (1996), “Obesity profoundly affects quality of life. Bodily pain is a prevalent problem among obese persons seeking weight loss and may be an important consideration in the treatment of this population.” Therefore, it is the purpose of this study to detect changes in functional performance of overweight individuals during a 12 week period of weight loss.

III. METHODS

This study examined the relationship between changes in both body weight and lean body mass and changes in muscular strength and function in overweight and obese adults. To examine these scientific questions the following methods and procedures were implemented. All procedures were approved by the Institutional Review Board (IRB) at the University of Pittsburgh, and written informed consent was obtained from all participants prior to their participation in this study.

This study was conducted as a sub-study to a 12-week randomized clinical weight loss trial. This sub-study was 12-weeks in duration and provided an initial opportunity to examine changes in body weight, body composition, muscular strength, and functional ability. The main clinical trial did not systematically incorporate resistance exercise into the intervention, which allowed this sub-study to examine the natural changes in muscular strength and functional ability independent of changes that may have resulted from resistance exercise training.

3.1. Subjects

Seventy-five individuals with body mass index (BMI) ranging from 25.0 to 39.9 kg/m^2 (classified as overweight or obese) and age ranging from 18 to 55 years participated in this study. Randomization was performed blocking on gender (male and female) and BMI (25-29.9, 30-34.9, and 35-39.9 kg/m^2). Individuals were excluded from participation based on the following criteria:

3.2. Exclusion Criteria

1. Reporting regular exercise participation of at least 20 minutes per day on at least 3 days per week during the previous six months.
2. Diabetes, hypothyroidism, or other medical conditions which would affect energy metabolism.
3. Women who are currently pregnant, pregnant within the previous six months, or planning on becoming pregnant within the next 18 months.

4. Non-medicated resting systolic blood pressure >160mmHg or non-medicated resting diastolic blood pressure >100mmHg, or taking medication that would affect blood pressure.
5. Taking medication that would affect resting heart rate of the heart rate response during exercise (e.g. beta blockade).
6. Arrhythmia on resting or exercise electrocardiogram that would indicate that vigorous exercise was contraindicated.
7. History of myocardial infarction or valvular disease.
8. Weight loss of >5% of body weight within the previous 12 months.
9. History of orthopedic complications that would prevent optimal participation in the exercise component (e.g., heel spurs, severe arthritis).

3.3. Recruitment

Subjects were recruited through a series of television, newspaper, radio, and direct mail announcements. Potential subjects were informed to contact the investigators at the University of Pittsburgh Physical Activity and Weight Management Research Center. Individuals were asked to participate in a brief telephone interview to determine initial eligibility. Eligible individuals were invited to attend a group orientation where they received a detailed description of the study. It was estimated that the orientation session would take 60-90 minutes to complete. All participants interested in participating in the study completed a detailed medical history (Appendix A) and a physical activity readiness questionnaire (PAR-Q) prior to participating in this study (Appendix B). Participants also provided written clearance from their primary care physician (Appendix C) and written informed consent prior to participating in this study. Moreover, all participants completed a submaximal graded exercise test that was reviewed by a cardiologist as part of the baseline assessment for this study.

3.4. Experimental Design

This study used a prospective observational design. All participants participated in a 12-week behavioral weight loss program that promoted a reduction in energy intake and an increase in energy expenditure in the form of aerobic exercise, primarily in the form of brisk walking. These intervention components are described in detail below.

This study was a sub-study of a randomized clinical trial. The clinical trial involved individuals being randomized to one of three intervention conditions. The differences in the three interventions involved strategies to promote adherence to the aerobic exercise program. However, these interventions did not target changes in resistance exercise that may affect the outcome of this observational sub-study.

3.5. Intervention Components

Eligible subjects were randomized to one of three intervention groups:

1) Standard In-Person Behavioral Weight Loss Program (SBWP): Subjects in this intervention group received an in-person standard behavioral weight control program following a clinical treatment model.
2) Intermittent Technology-Based Behavioral Weight Control Program (INT-TECH): Subjects in this group received all of the components included in the SBWP; however, individuals in this intervention group utilized the HealthWear™ System during weeks 1, 5, and 9 of the intervention period.
3) Continuous Technology-Based Behavioral Weight Control Program (CON-TECH): Subjects in this group received all of the components included in the SBWP; however, individuals in this intervention group utilized the HealthWear™ System daily throughout the intervention period.

3.5.1. Intervention Contact

Subjects in all groups (SBWP, INT-TECH, CON-TECH) received an in-person standard behavioral weight control program that followed a clinical treatment model. The in-person visits were conducted in an individual session by a trained interventionist. During the in-person sessions the interventionist integrated behavioral strategies to assist with weight control. Body weight was measured at each in-person session, with subjects being encouraged to monitor their body weight on their own during weeks when no in-person visits were scheduled. All sessions were conducted at the Physical Activity and Weight Management Research Center at the University of Pittsburgh.

3.5.2. Behavioral Lesson Content

All in-person visits focused on a specific behavioral topic related to weight loss, eating behaviors, or exercise behaviors (See Table 3.1). The interventionist facilitated a discussion related to the specified topic. At each visit, participants were also provided written material as a supplement. During weeks that subjects did not attend an in-person session, they were mailed a behavioral lesson to offer a form of consistent weekly contact and support.

Table 3.1. Behavioral Lesson Titles

Week Number	Delivery Format	Lesson Title
1	IP	Behavioral approach to changing eating and exercise habits
2	IP	Healthy food choices
3	IP	Developing and implementing an exercise program
4	IP	Motivation
5	M	Energy balance
6	IP	Food guide pyramid/portion control
7	M	Stimulus control/Urge management
8	IP	Exercise barriers
9	M	Eating out
10	IP	Evaluating progress/Looking ahead
11	M	Problem solving
12	M	My time, my values

IP = in-person lesson; M = mailed lesson

3.6. Dietary Intervention

Subjects were instructed to reduce calorie intake to 1200-1800 calories per day based on body weight (<200 pounds = 1200 kcal/day; 200-250 pounds = 1500 kcal/day; >250 pounds = 1800 kcal/day) and to reduce fat intake to 20-25% of total dietary intake. Subjects were provided with sample meal plans and menus to assist them with making appropriate food selections, and these were developed by registered dietitians. Subjects recorded their eating behaviors in a weekly food diary (SBWP) or on the HealthWear™ System website (INT-TECH and CON-TECH) that was reviewed weekly by the intervention staff. Subjects participating in eating behaviors inconsistent with the recommendations for this study were counseled by the registered dietitian affiliated with this study.

3.7. Exercise Recommendations

All subjects were instructed to exercise at a moderate intensity on 5 days per week. Initially subjects were instructed to exercise 20 minutes per day, this duration was gradually progressed to at least 40 minutes per day. The exercise progression was 10 minutes per day in 4 week intervals. Subjects were encouraged to participate in activity that is at minimum moderate in intensity, with an

RPE set at 11-13 on the 15-point Borg scale and/or heart rate range between 55-70% of maximal heart rate. Activities that were consistent with this intensity level are similar to “brisk walking”.

3.8. Assessments Procedures

All subjects participated in assessments at baseline and following 12-weeks of weight loss treatment. These assessments included the following procedures which provided the data for this study.

<u>Weight:</u> Body weight was assessed using a calibrated balance-beam scale. Subjects were clothed in a light-weight cloth hospital gown, and weight was measured to the nearest 0.25 pounds.

<u>Height:</u> Height was measured using a wall-mounted stadiometer without the subject wearing shoes. Height was measured to the nearest 0.1 centimeter.

<u>Body Mass Index (BMI):</u> Body mass index was computed from measurements of weight and height (kg/m^2).

<u>Body Composition:</u> Body composition was assessed using an RJL bioelectrical impedance analyzer (BIA) which provided an estimate of lean body mass and body fatness using the equation proposed by Segal (1988). Subjects were instructed to fast, except for water, for at least 4 hour prior to this assessment.

<u>Muscular Strength:</u> Muscular strength was assessed using a 1-repetition maximal (1-RM) test. A Zuma Universal Gym was used to perform the 1-RM test. Upper body muscular strength was assessed using the chest press exercise, with lower body strength assessed using the leg extension exercise. The following specific procedures were used when performing these assessments.

ACSM guidelines for 1-RM testing were followed accordingly to determine muscular strength using the vertical chest press. The subject was seated at the machine with feet flat on the floor and back against the support pad. Both hands were in a neutral grip position grasping the handles located at chest level. A complete repetition was constituted as a lift where the subject's arms were extended in front of them until their elbows were approximately 5° short of full extension and then returned back to the starting position. The subject first warmed-up with 5-10 repetitions at 40-60% of their perceived maximum. Following a one minute rest with light stretching, the subject performed 4-5 repetitions at 60-80% of their perceived maximum. Then a small amount of weight was added, and a 1-RM lift was attempted. If the lift was successful, a rest period of 1-2 minutes was provided. The goal was to find the 1-RM within 3-5 maximal efforts. The 1-RM was reported as the weight of the last successfully completed lift (*ACSM's Guidelines for Exercise Testing and Prescription. 6th edition,* 2000*).* The test-retest reliability of the 1-RM test varies from .93-.98 (Faigenbaum et al).

ACSM guidelines for 1-RM testing were followed accordingly to determine muscular strength using the leg extension. The subject was seated at the machine with back against the support pad, knees in alignment with the pivot point of the machine, and ankles behind the ankle pad. The subjects were instructed to extend their knees as fully as possible, from 90° of flexion to full extension, then to return to their starting position. A complete repetition was constituted as a lift where the subject's legs were extended to their full range of motion (determined in the unweighted position) and then returned back to the starting position. The subject first warmed-up with 5-10 repetitions at 40-60% of their perceived maximum. Following a one minute rest with light stretching, the subject performed 4-5 repetitions at 60-80% of their perceived maximum. Then a small amount of weight was added, and a 1-RM lift was attempted. If the lift was successful, a rest period of 1-2 minutes was provided. The goal was to find the 1-RM within 3-5 maximal efforts. The 1-RM was reported as the weight of the last successfully completed lift (*ACSM's Guidelines for*

Exercise Testing and Prescription. 6th edition, 2000*).* The test-retest reliability of the 1-RM test varies from .93-.98 (Faigenbaum et al).

Function: The sit-to-stand test, a test generally used in the geriatric population, was used to assess lower-body strength and functional performance (Bohannon et al, 1995, Rikli et al, 1999, & Jones et al, 1999). The participant was instructed to sit in the middle of a chair with his or her back straight, feet flat on the floor, and arms crossed at the wrists and held against the chest. The participant rose to a full stand and then returned to a fully seated position as many times as he or she could in 30 seconds. Participants were instructed not to use momentum or their hands to assist them to a fully standing position. The score was recorded as the number of stands completed in 30 seconds. If the participant was more than halfway up at the end of 30 seconds, it was counted as a full stand. Before the test was performed, a verbal description and a visual demonstration was provided. Each of the participants practiced the movement to minimize the effect of a learning curve from pre to post test.

Physical Activity: Physical activity was assessed using the questionnaire developed by Paffenbarger and colleagues for the Harvard Alumni Study (1978, 1986). This questionnaire provided an estimate of energy expenditure per week of activities performed during leisure-time which may include exercise, sports, and other forms of recreation. In addition, this questionnaire included walking and stair climbing. This questionnaire is provided in Appendix D.

3.9. Data Analysis

Data analysis were conducted using SPSS statistical software, with statistical significant defined as $p \leq 0.05$. Data were entered into an Access Database and converted to the appropriate file for data analysis. The data were initially analyzed using descriptive statistics, which included mean, standard deviation, range, and tests for normal distribution of the data. Data were also analyzed using dependent t-tests to determine if the outcomes measures in this study changed significantly over the 12 weeks of treatment. One-way analysis of variance (ANOVA) was used to determine if there were differences in the change in the outcome variable based on randomized group assignment.

The primary and secondary hypotheses were tested using correlation coefficients. Pearson Product Moment correlation coefficients were used for data analysis when the data were considered to be normally distributed. However, when data were found to be skewed, Spearman Rank Order correlation coefficients were used.

3.10. Power Analysis

The primary and secondary hypotheses in this study were examined using correlation coefficients. Because on this, the power analysis was conducted based on the ability to detect significant correlations between the variables of interest. Thus, the power analysis was conducted to determine if the 75 subjects available for this study would provide adequate statistical power to examine the primary hypotheses in this study. Based on an available sample of 75 subjects, and assuming the possibility of 15 percent attrition, this would allow for 64 subjects to complete this study. This sample size allowed for correlations of 0.40 to be detected with at least 0.95 statistical power. Moreover, this sample size allowed for 0.80 statistical power to detect a correlation of 0.30 in this study.

IV. RESULTS

The purpose of this study was to examine the relationship between changes in body weight and lean body mass and changes in muscular strength and function during a 12 week weight loss intervention in overweight and obese adults. This study was a pretest-posttest clinical weight loss intervention with assessments performed at 0 and 12 weeks of participation. The primary dependent variables were body weight, body mass index (BMI), body composition, strength (1-RM chest press, 1-RM leg extension, grip strength), and function (sit-to-stand).

4.1. Subject Characteristics

The subjects in this investigation were 57 adults (1 male, 56 females). Eligible subjects were between 21 and 55 years of age, with a BMI ranging from 25.0 to 39.9 kg/m^2. Descriptive characteristics are presented in Table 4.1. To examine if the results of the one male subject in this study influenced the results, the statistical analyses were performed with and without the male subject. There was no difference in the pattern of the results when the male subject was included in the analyses, and therefore the results are presented which include the male subject.

Table 4.1 Characteristics of Subjects at Baseline

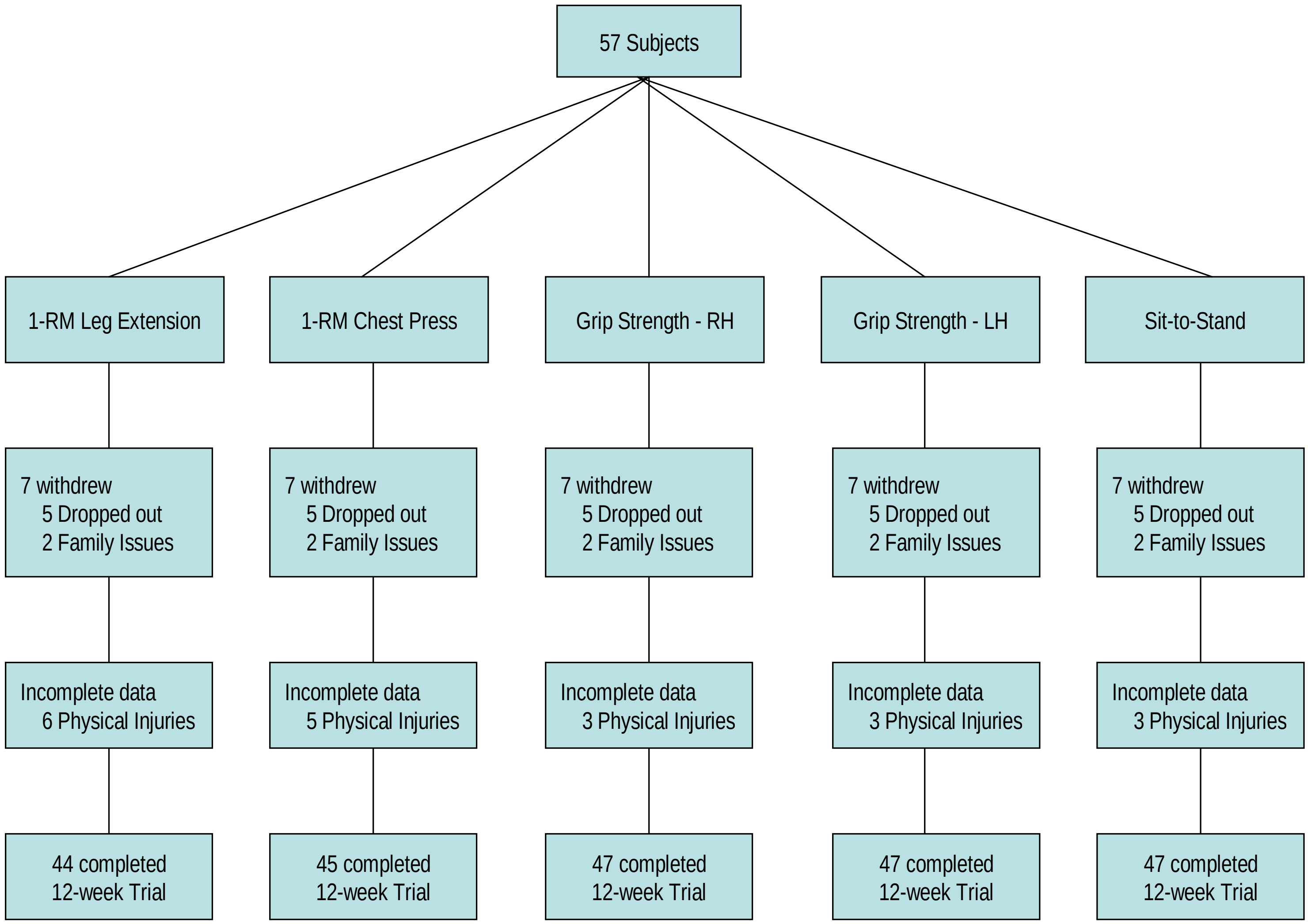
Variable	Total (N = 57)	Completers (N = 50)	Non-Completers (N = 7)
Age (years)	41.3 ± 8.7	42.5 ± 8.1	32.6 ± 8.4*
Height (cm)	163.7 ± 5.5	163.3 ± 5.6	165.9 ± 2.5
Weight (kg)	88.8 ± 9.1	88.4 ± 9.1	92.9 ± 9.1
% Minority	38.6 (N=22)	32.0 (N=16)	85.7 (N=6)
BMI (kg/m^2)	33.1 ± 2.8	33.1 ± 2.7	33.7 ± 2.8
Body comp.(% fat)	42.4 ± 3.8	42.3 ± 3.8	43.0 ± 3.7
1-RM Leg (kg)	79.1 ± 24.4	78.9 ± 25.6	79.7 ± 19.9
1-RM Chest (kg)	61.8 ± 14.5	60.8 ± 14.8	65.3 ± 13.5
Grip Strength Right Hand (kg)	32.85 ± 6.0	32.7 ± 6.4	33.4 ± 4.5
Grip Strength Left Hand (kg)	31.6 ± 6.0	31.6 ± 6.3	31.5 ± 4.7
**Sit-to-Stand (reps)	14.4 ± 3.3	14.5 ± 3.4	14.2 ± 3.0

* Indicates statistical significance between Completers and Non-Completers at $p<0.05$.
**Number of sit-to-stands performed in 30 seconds.

4.2. Retention Rates

A total of 50 subjects (88% of all subjects) provided objective weight data at baseline and 12 weeks; these subjects were referred to as "completers". Those subjects not providing objective data at baseline and 12 weeks are referred to as "non-completers" (N=7, 12% of all subjects), with study withdrawal resulting from the subject electing to discontinue participation for unknown reasons (N = 5) or as a result of conflicting family issues (N = 2). In addition, because of non-study related physical injuries (i.e. knee pain, wrist sprains, surgery) at the 12-week assessment, 6 participants were unable to perform the 1-RM leg extension, 5 participants were unable to perform the 1-RM chest press, 3 unable to perform the grip strength test, and 3 unable to perform the sit-to-stand test. See Figure 4.1 for assessment completion details.

Figure 4.1 Assessment Completion at baseline and 12 weeks



4.3. Absolute and Relative Changes

4.3.1. Absolute and Relative Change in Body Weight and Lean Body Mass

To examine the specific aims related to the effect of the intervention on body weight and lean body mass (LBM), a series of paired sample t-tests were performed. There was a significant reduction in absolute body weight (5.2 $\pm$ 3.4 kg; $p < 0.001$) and relative weight loss (5.9 $\pm$ 5.6%; $p<0.001$). In addition, there was a significant reduction in absolute LBM (0.8 kg $\pm$ 1.7 kg; $p = 0.002$) and relative LBM loss (1.2 $\pm$ 3.3%; $p<0.001$) with fat mass decreasing by 4.5 $\pm$ 6.5 kg ($p<0.001$). Percent body fat decreased from 42.4 $\pm$ 3.8% at baseline to 39.5 $\pm$ 4.5% at the completion of the intervention ($p<0.001$).

4.3.2. Absolute and Relative Change in Strength and Function

To examine aims related to the effect of the intervention on muscular strength and function, a series of paired sample t-tests were performed. These results are shown in Table 4.2. Absolute loss in leg and chest strength was 4.9 $\pm$ 11.4 kg ($p<0.001$) and 2.3 $\pm$ 4.2 kg ($p = 0.003$), respectively. The relative loss of leg and chest strength was 13.7 $\pm$ 13.3% ($p<0.001$) and 8.3 $\pm$ 11.6% ($p<0.001$) respectively. Although not statistically significant, grip strength decreased by 0.5 kg $\pm$ 6.4 kg (1.2 $\pm$ 0.9 %) ($p = 0.37$). Functional testing included the sit-to-stand test and this increased by 1.1 $\pm$ 3.8 stands (7.6 $\pm$ 33.6%) ($p = 0.05$) across the 12 week intervention.

4.3.3. Absolute and Relative Change in Leisure-Time Physical Activity

To examine the aim related to the effect of the intervention on leisure time physical activity, a paired sample t-test was performed. These results are shown in Table 4.2. Absolute increase in leisure time physical activity was 1018.6 $\pm$ 2161.7 kcal/wk ($p<0.002$) and relative increase was 113.6 $\pm$ 242.8 kcal/wk ($p<0.002$) across the 12 week intervention.

Baseline and 12 week leisure-time physical activity data were examined to determine the prevalence of subjects' participation in resistance exercise. At baseline, 23 sessions were reported that were not walking activity. Of these, 3 of the 23 (13% of the sessions) sessions were resistance exercise. At 12 weeks, 31 sessions were reported that were not walking activity. Of these, 3 of the 31 (9.6% of the sessions) sessions were resistance exercise. Thus, it appears that the majority of exercise was in the form of walking or non-resistance forms of physical activity.

Table 4.2 Change and Percent Change in Weight, Lean Body Mass, Strength, Function, and Leisure Time Physical Activity (LTPA)

Variable	Baseline	12 Weeks	Change	% Change
Weight (kg)	88.4 ± 9.1	83.2 ± 9.6	-5.2 ± 3.4**	-5.9 ± 5.6**
LBM (kg)	50.9 ± 4.9	50.1 ± 4.7	-0.8 ± 1.7**	-1.5 ± 2.9**
1-RM Leg (kg)	35.9 ± 11.8	30.9 ± 10.1	-4.9 ± 11.4**	-13.7±13.3**
1-RM Chest (kg)	27.7 ± 6.7	25.35 ± 6.4	-2.3 ± 4.2**	-8.3 ± 11.6**
Grip Strength (kg)	32.1 ± 6.3	31.6 ± 6.6	-0.5 ± 6.4	-1.2 ± 0.9
Sit-to-Stand•	14.5 ± 3.4	15.6 ± 4.6	1.1 ± 3.8*	7.6 ± 33.6*
LTPA (kcal/wk)	896.3 ± 890.4	1914.9 ± 2080.5	1018.6 ± 2161.7**	113.6 ± 242.8**

*Indicates statistical significance at $p \leq 0.05$
**Indicates statistical significance at $p \leq 0.01$
• Number of sit-to-stands completed in 30 seconds

4.4. Results of Correlational Analyses

4.4.1. Change in Body Weight and Muscular Strength

To examine the hypothesized relation between change from 0 to 12 weeks in body weight and change in muscular strength (1-RM leg extension, 1-RM chest press, and grip strength), Pearson Product Moment correlation analyses were performed. Results revealed non-significant associations between change in body weight and 1-RM leg extension ($r = 0.01$), 1-RM chest press ($r = 0.19$) and grip strength ($r = -.09$). These results are shown in Table 4.3. Based on these findings, the proposed hypothesis that change in body weight would be significantly correlated with change in muscular strength was not accepted.

4.4.2. Change in Body Weight and Function

To examine the hypothesized relation between change from 0 to 12 weeks in body weight and change in function, measured using the sit-to-stand test, Pearson Product Moment correlation analyses were performed. Results revealed a significant inverse correlation between the percent change in body weight and the percent change in function ($r = -0.35$, $p = 0.01$), demonstrating that a significant percent reduction in body weight was associated with improved function based on the sit-to stand test. The relation between absolute change in body weight and change in physical function was $r = -0.24$ ($p = 0.10$). These results are shown in Table 4.3. Based on these findings, the proposed hypothesis that percent reduction in body weight would be associated with improved physical function was accepted.

4.4.3. Change in LBM and Muscular Strength

To examine the hypothesized relation between change from 0 to 12 weeks in lean body mass and change in muscular strength (1-RM leg extension, 1-RM chest press, and grip strength), Spearman Rank Order correlation analyses were performed due to a violation of normality (positive skewness) in the LBM, 1-RM leg extension, and grip strength data. Results revealed non-significant associations between the change in lean body mass and 1-RM leg extension ($r = -0.14$), 1-RM chest press ($r = 0.10$), and grip strength ($r = -0.06$). These results are shown in Table 4.3. Thus, based on these findings, the proposed hypothesis that change in LBM would be correlated with change in muscular strength was not accepted.

4.4.4. Change in LBM and Physical Function

To examine the hypothesized relation between change from 0 to 12 weeks in lean body mass and change in physical function, measured using the sit-to-stand test, Spearman Rank Order correlation analyses were performed due to a violation of normality (positive skewness) in the LBM and sit-to-stand data. Results revealed non-significant associations between the change in lean body mass and physical function ($r = -0.06$). These results are shown in Table 4.3. Thus, based on these findings, the proposed hypothesis that change in LBM would be associated with a change in physical function was not accepted.

Table 4.3 Correlation between Changes in Weight and LBM and Changes in Strength and Physical Function

	Change Scores**			
	1-RM Leg	1-RM Chest	Grip Strength	Sit-to-Stand
Change Weight**	r = 0.01	r = 0.19	r = -0.09	r = -0.24
Percent Change Weight**	r = 0.02	r = 0.19	r = -0.07	r = -0.35*
Change LBM**	r = -0.14	r = 0.09	r = 0.01	r = -0.06
Percent Change LBM**	r = -0.09	r = 0.09	r = -0.05	r = -0.11

* Indicates statistical significance found at p<0.05 level
**Computed as Baseline minus 12-week value

4.4.5. Change in Muscular Strength and Change in Function

To examine the hypothesized relation between change from 0 to 12 weeks in muscular strength and change in function, Pearson Product Moment correlation analyses were performed. Results revealed non-significant associations between the change in muscular strength and function (1-RM leg extension, r = 0.12; 1-RM chest press, r = 0.17; grip strength, r = 0.24). Based on these findings, the proposed hypothesis that change in muscular strength would be significantly associated with change in physical function was not accepted.

4.4.6. Leisure Time Physical Activity, Strength and Function

To examine the hypothesized relation between change in leisure time physical activity and change in both muscular strength and function, Spearman Rank Order correlation analyses were performed due to a violation of normality (positive skewness) in the leisure time physical activity and function data. Results revealed non-significant associations between the change in leisure time physical activity and the change in muscular strength (1-RM leg extension, r = -.05; 1-RM chest press, r = -0.06; grip strength, r = 0.05) and physical function (r = 0.09). These results are shown in Table 4.4. Based on these findings, the proposed hypotheses that change in physical activity would be significantly associated with change in strength and physical function were not accepted.

Table 4.4 Spearman Rank Order Correlations between change in Leisure Time Physical Activity (LTPA) and Strength and Function

	Change Scores*			
	1-RM Leg	1-RM Chest	Grip Strength	Sit-to-Stand
Change LTPA*	r = -0.05	r = -0.06	r = 0.05	r = -0.09
Percent Change LTPA*	r = - 0.05	r = 0.07	r = -0.05	r = -0.03

* Computed as Baseline minus 12-week value

4.5. Summary of Results

This 12-week behavioral weight loss intervention produced a statistically significant decrease in body weight, lean body mass, 1-RM chest press, and 1-RM leg extension ($p \leq 0.05$), with no significant change in grip strength from baseline to 12-weeks (see Table 4.2). However, there was a significant increase in physical function (sit-to-stand score) from baseline to 12-weeks ($p \leq 0.05$) (Table 4.2). Percent decrease in body weight was significantly associated with an increase in physical function ($r = 0.35$; $p<0.05$) (Table 4.3). These findings indicate that despite a potential decrease in LBM and strength that is observed with weight loss, weight loss does result in an increase in physical function in overweight and obese adults. This would support an additional benefit of weight loss that may be important for improving health and quality of life of overweight and obese adults.

V. CONCLUSION

5.1. Introduction

Behavioral interventions that combine a reduction in energy intake (diet) with an increase in energy expenditure (physical activity) have shown to produce a weight loss of approximately 10 percent of initial body weight over a 5 to 6 month period (Wing, 2001). However, 10 to 47 percent of this total weight lost is from a loss of lean body mass (Ross et al, 1996; Trombetta et al, 2003; Bryner et al, 1999; Byrne et al, 2003; & Lynch et al, 2000). It has been proposed that a loss of lean body mass could have potential negative implications on muscle strength and function (Al-Abdulwahab, 1999; & Harris, 1997). Therefore, the purpose of this study was to examine the relationship between the changes in body weight and lean body mass with changes in muscular strength and function in overweight and obese adults across a 12 week weight loss intervention.

5.2. Discussion of Results

5.2.1. Effect of Intervention on Weight Loss

The present study produced a significant weight loss of 5.2 $\pm$ 3.4 kg as a result of a 12 week weight loss intervention (see Table 4.2). The intervention in this current study consisted of behavioral counseling, energy reduction (1200 to 1500 kcals/day), and exercise (30-40 min/day on 5 d/wk). The weight loss in this study was similar to other weight loss studies of this duration. For example, Jensen et al. (2004) produced a mean weight loss of 4.3 $\pm$ 5.5 kg during a 3 month weight loss intervention, whereas Ross et al. (2000) produced a slightly higher weight loss of 7.5 $\pm$ 0.75 kg during a 3 month intervention. Thus, the changes observed in this study may be generalizable to other studies that have been of similar duration (12 weeks) and have resulted in a similar magnitude of weight loss.

5.2.2. Effect of Weight Loss on Lean Body Mass

The 12-week intervention resulted in a significant reduction in body weight (5.2±3.4 kg), and this also resulted in a significant reduction in LBM (0.8±1.7 kg) (see Table 4.2). These results confirm the results of other studies that have demonstrated that lean body mass is compromised during weight loss interventions (Ross et al, 1996; Kraemer et al, 1999). For example, Ross et al. (2000) reported a 1.5 ± 0.9 kg loss of lean body mass during a 3 month intervention. This reduction in lean body mass could have several negative implications including loss of strength and physical function. Sarcopenia, which is a reduction in the size or number of muscle fibers, especially Type II muscle fibers, could lead to a decreased ability of the muscle to generate power (Jespersen, 2003). This reduction in the ability to generate muscular power may result in a compromised ability to perform activities of daily living (Jespersen, 2003). This would suggest that weight loss interventions should be potentially concerned about the associated reductions in LBM. However, the results of this study do not support this conclusion. The results of this study demonstrated that while there was a significant reduction in LBM there was also an increase in physical function (see Table 4.2). Moreover, the loss of LBM was not associated with changes in physical function (see Table 4.3). Thus, additional research is needed to understand the relationship between changes in LBM and physical function with weight loss in overweight and obese adults.

5.2.3. Effect of Weight Loss on Changes in Muscular Strength

The findings indicated that there was a significant decrease in muscle strength from baseline to 12 weeks for 1-RM chest press (-2.3 ± 4.2 kg) and 1-RM leg extension (-4.9 ± 11.4 kg). These results represented a 13.7 ± 13.3% decrease in 1-RM leg extension, and an 8.3 ± 11.6 % decrease in chest press. There was not a significant change in grip strength from baseline to 12 weeks. The pattern of reduction in muscular strength is similar to the 6% reported by Donnelly et al. (1994), however this is somewhat greater than the 1.5% reported by Kraemer et al. (1997). The loss of strength may be overcome during a weight loss intervention by incorporating strength training into the intervention. As determined by Pronk et al. (1992), individuals on a very low calorie diet for ninety days who performed strength training exercises were able to increase upper and lower body strength.

A decrease in muscle strength could have negative implications on physical function and activities of daily living (Lord, 2003). In addition, muscle strength may be important to reduce the risk of falls and to diminish the loss of personal independence, especially in older adults (Lord, 2003). However, the results of this study demonstrate that the loss of muscular strength resulting from weight loss may not negatively impact physical function.

5.2.4. Effect of Weight loss on Physical Function

The findings of this study indicate that there is a significant increase in physical function resulting from weight loss across a 12-week intervention in overweight and obese adults. The 5.9$\pm$5.6% reduction in body weight was associated with a 7.6% increase in physical function as assessed by the sit-to-stand test ($r = 0.35$). Of potential importance is that the increase in function occurred despite observed reductions in LBM and muscular strength (see Tables 4.3 and 4.4). This implies that a modest reduction in body weight can improve physical function in overweight adults during a 12-week weight loss intervention. It may be important to maintain the reduction in body weight to maintain the improvement in physical function, which may be especially important to improve the independence of overweight and obese adults with advancing age (Lord, 2003).

5.3. Recommendations for Maintaining LBM, Muscle Strength, and Physical Function

Resistance training has been shown to be an effective tool for maintaining and/or improving lean body mass, muscle strength and function (Rooks, 1997). Kraemer et al. (1997) showed an increase in muscle strength during a 12-week weight loss intervention that included a combination of diet plus aerobic exercise plus resistance training (DES) for females and males. In addition to the diet and cardiovascular exercise, subjects performed 12 resistance training exercises three days/week. The subjects alternated between heavy loads (5-7 RM) and lighter loads (8-10 RM) during the week. Subjects progressed from one to three sets with a short rest between sets when using moderate loads (1 min) and longer rest periods (2-3 min) when using the heavier loads. The females who participated in the DES intervention demonstrated significant increases in muscular strength (14% increase in bench press, 25% increase in squat), with a similar pattern shown for males (19.6% increase in bench press, 32.6% increase in squat) (Kraemer et al, 1999). Thus, it was concluded that muscle strength can be maintained or improved during a 12-week weight loss intervention when resistance exercises are performed 3 days/week for three sets of alternating repetitions: 5-7 repetitions (heavy load) and/or 8-10 repetitions (light load).

Bryner et al. (1999) studied twenty subjects (17 women, three men), mean age 38 years over 12 weeks. These subjects were randomly assigned to a standard treatment control plus diet, or resistance exercise plus diet. The control plus diet group exercised 1 hour four times/week by walking, biking, or stair climbing, whereas the resistance exercise plus diet group performed resistance training 3 days/week in the form of a circuit. Both groups consumed 800 kcals/day in the form of a liquid diet. At the end of the 12 weeks, it was found that the control plus diet group lost 4 kg of lean body mass (22% of total weight lost) whereas the resistance exercise plus diet group only lost .8 kg of lean body mass (5.5% of total weight lost) which was not statistically significant. Thus, it was concluded that lean body mass can be maintained during a 12-week weight loss intervention by including 3 days/week of resistance circuit training.

Furthermore, Ballor et al. (1988) assessed the individual and combined effects of weight loss and weight training on body weight and body composition. Forty obese women were randomly assigned to one of four groups for an 8 wk weight-loss study. These groups were control (C), diet without exercise (DO), diet plus weight training (DPE), and weight training without diet (EO). Those in the DPE and EO groups completed eight resistance training exercises 3 days/week for two sets of ten repetitions. A third set of repetitions was completed until fatigue. Results demonstrated that lean body weight increased for EO (1.07 kg) compared with DO (-0.91 kg) and C (-0.31 kg) and for DPE (0.43 kg) compared with DO. It was concluded that adding resistance training exercise to a calorie restricted program results in maintenance of lean body weight when compared with diet only.

These results indicate that resistance exercise can increase muscular strength during periods of weight loss, and this may be a result of the impact of resistance exercise on LBM. Thus, interventions may need to include resistance exercise performed at a similar dose and intensity to these studies to observe significant changes in LBM and strength in overweight and obese adults during weight loss. However, it is unclear if resistance exercise of a lower dose or intensity would result in similar improvements in LBM and muscular strength in overweight and obese adults during weight loss. Moreover, it is unclear if overweight and obese adults would remain adherent to participating in this form of exercise long-term.

5.4. Limitations and Future Research

The current study posed several limitations which should be addressed in future research.

1) This study examined the effects of a 12-week intervention on weight loss, body composition, strength, and function. Thus, it is unclear if a longer duration weight loss intervention would result in different findings with regards to changes in body weight, LBM, strength or physical function. Therefore, future studies should examine the effects of long-term weight loss interventions (i.e. 12 months) on lean body mass, strength, and function.
2) This study used the sit-to-stand test to assess physical function. However, this test may only provide information about function related to the trunk and lower extremities, which may have provided a limited perspective of the effect of weight loss on physical function in

overweight and obese adults. Future studies should use more comprehensive assessments of physical function to examine the impact of weight loss on these parameters.

3) This study included 57 subjects, which consisted of 56 females and 1 male. This prohibited the examination of the gender effects of the intervention on the outcome variables in this study. Future studies should examine if the pattern of results is consistent between genders.
4) This study included subjects who were between the ages of 21 and 55 years. It is unclear to which age group these results are generalizable. Therefore, future studies should examine the effect of weight loss on changes in LBM, muscle strength and function in distinct age groups including older and younger adults.
5) This study included a standard behavioral weight loss intervention to reduce energy intake and increase physical activity. However, the intervention did not include a resistance exercise component, which does not allow for this study to examine the impact of resistance exercise on weight loss, LBM, strength or physical function. Therefore, future studies should examine the effect of resistance exercise within the context of a behavioral weight loss intervention on changes in physical function in overweight and obese adults. Moreover, future studies should examine the dose-response of aerobic and resistance exercise needed to elicit desired changes in body weight, LBM, strength and physical function during a weight loss intervention for overweight and obese adults.

5.5. Summary

In conclusion, this study found that a 12 week weight loss intervention decreased body weight, lean body mass, and strength. Conversely, a significant increase in physical function was found after this 12 week weight loss intervention. A significant correlation was found between the reduction in body weight and physical function, suggesting that a moderate reduction in body weight (5.5%) can lead to a significant increase in function (7.6%) as shown in this study. This is important because overweight adults who lose weight can increase their physical function regardless of the loss of LBM and strength that may naturally occur with weight loss. This may have implications for increasing health-related quality of life in overweight and obese adults, and this may further highlight the health implications of weight loss.

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APPENDIX A

GENERAL HEALTH HISTORY

Subject ID:____

DATE: / /

1. Do you have or have you ever had any of the following medical conditions?

				Approximate Date of Diagnosis	Describe the Problem
a.	Heart Attack	o yes	o no	___________	_____________
b.	Angina (chest pain on exertion)	o yes	o no	___________	_____________
c.	Irregular Heart Problems	o yes	o no	___________	_____________
d.	Other Heart Problems	o yes	o no	___________	_____________
e.	Stroke	o yes	o no	___________	_____________
f.	Fainting Spells	o yes	o no	___________	_____________
g.	High Blood Pressure	o yes	o no	___________	_____________
h.	High Cholesterol	o yes	o no	___________	_____________
i.	Thyroid Problems	o yes	o no	___________	_____________
j.	Cancer	o yes	o no	___________	_____________
k.	Kidney Problems	o yes	o no	___________	_____________
l.	Liver Problems	o yes	o no	___________	_____________
m.	Gout	o yes	o no	___________	_____________
n.	Diabetes	o yes	o no	___________	_____________
o.	Emotional/Psychiatric Problems	o yes	o no	___________	_____________
p.	Drug/Alcohol Problems	o yes	o no	___________	_____________

2. Do you have any medical problems that would prevent you from participating in a regular walking program? o yes o no

If yes, please describe the problem:____

____

3. Have you participated in a regular exercise program over the past 6 months which consists of at least 20 minutes of activity, 3 days per week? o yes o no

Please describe:____

____

4. Do you have to sleep with extra pillows or have to sit up in the middle of the night because of shortness of breath? o yes o no

5. Please list <u>all</u> medications that you are currently taking on a regular basis (make sure to indicate if you are taking medication for high blood pressure or cholesterol):

MEDICATION	REASON FOR TAKING
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________
______________________________	______________________________

6. Over the last 6 months, on how many weekdays (Monday through Friday) do you usually drink wine, beer, or liquor on average?

(0)	o Never	(4)	o 2 days/week
(1)	o Less than once/month	(5)	o 3 days/week
(2)	o 1-2 times/month	(6)	o 4 days/week
(3)	o 1 day/week	(7)	o 5 days/week

7. On those weekdays that you drink wine, beer, or liquor how many drinks do you have? OO

8. Over the last 6 months, on how many weekend days (Saturday and Sunday) do you usually drink wine, beer, or liquor?

(0)	o Never	(4)	o 1 weekend day/week
(1)	o Less than once/month	(5)	o 2 weekend days/week
(2)	o 1-2 times/month		

9. On those weekend days that you drink wine, beer, or liquor how many drinks do you have?

10. In the past year, have you regularly smoked cigarettes, pipes, cigars, or used chewing tobacco?

			Please describe daily habit
Cigarettes	o yes	o no	______________________
Pipe	o yes	o no	______________________
Cigars	o yes	o no	______________________
Chewing Tobacco	o yes	o no	______________________

11. Do you plan to spend frequent time out of town on business or vacation during the next 18 months? o yes o no

Please describe:____

12. Is it possible that you will relocate in the next 18 months? o yes o no

Please describe: ____

WOMEN ONLY ANSWER THE FOLLOWING QUESTIONS

13. Are you currently pregnant? o yes o no

14. Were you pregnant within the past 6 months? o yes o no

15. Do you plan to become pregnant in the next 18 months? o yes o no

16. Have you gone through menopause or the change of life? o yes o no

17. Have you had a hysterectomy? o yes o no

18. When was your last menstrual period? DATE: / /

19. Do you take :

Birth Control Pills?	o yes	o no
Estrogens (ie. Premarin)?	o yes	o no
Progesterone (ie. Provera)?	o yes	o no

APPENDIX B

Physical Activity Readiness Questionnaire (PAR-Q)

Subject ID: ________________________________ Date: _____________

Please read the questions carefully and answer each one honestly: check YES or NO

1. Has your doctor ever said you have a heart condition and that you should only do physical activity recommended by a doctor?

   o yes o no

2. Do you feel pain in you chest when you do physical activity?

   o yes o no

3. In the past month, have you had chest pain when you were not doing physical activity?

   o yes o no

4. Do you lose your balance because of dizziness or do you ever lose consciousness?

   o yes o no

5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

   o yes o no

6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

   o yes o no

7. Do you know of any other reason why you should not do physical activity?

   o yes o no

Reference: American Medical Association: Guides to the Evaluation of Permanent Impairment. AMA, Chicago, 1990.

APPENDIX C

PHYSICIAN CONSENT TO PARTICIPATE IN A DIET AND EXERCISE PROGRAM AT THE UNIVERSITY OF PITTSBURGH

TO:	RETURN TO: (envelope provided)
________________ Physician's Name	John M. Jakicic, Ph.D.
	University of Pittsburgh
	Department of Health and Physical Activity
________________ Address	Physical Activity and Weight Management Research Center
	2100 Wharton Street, Suite 600
________________ City State Zip	Pittsburgh, PA 15203
	Telephone: (412) 488-4184
( ) ________________ Telephone Number	FAX: (412) 488-4174

Your patient ______________________________ has asked to participate in a diet and exercise program at the University of Pittsburgh. This is an 18 month research study designed to help patients to change their eating and exercise habits and to examine the impact that this will have on long-term weight loss and increases in physical fitness. This will involve the following:

1. A walking program that will be primarily home-based. The exercise will gradually be progressed from 20 minutes per day to as much as 40 minutes per day, 5 days per week. Exercise intensity will be set at 60-70% of the patient's maximal heart rate.
2. A diet program that will reduce energy intake to 1200-1500 calories per day, with dietary fat reduced to 20-30% of total energy intake.
3. A graded exercise test which involves walking on a motorized treadmill, with the workload gradually increasing every 3 minutes. The test will be terminated when the patient achieves 85% of their age-predicted maximal heart rate, or prior to this level if the individual experiences signs or symptoms that would indicate that exercise is contraindicated. Both blood pressure and heart rate will be monitored continuously. The ACSM Guidelines for Exercise Testing will be followed.
4. Behavioral modification techniques for changing exercise behaviors.
5. A list of additional factors that are exclusionary criteria for this study that you should consider are listed on the attached sheet.

****

Please indicate below if this program seems appropriate for your patient or if you see any contraindications for her participation (*please check the appropriate box below)*.

__ I know of no contraindications to this patient participating in any of the above components of the program.

__ I feel that this program would not be appropriate for this patient for the following reason(s):

____

____

____ ____________________

Signature of Physician Date

Please consider the following Inclusion and Exclusion Criteria as you evaluate whether your patient is capable of safely participating in the weight loss and exercise research study at the University of Pittsburgh.

Inclusion Criteria:	Exclusion Criteria:
• Female or Male • 18-55 years of age • BMI = 25-39.9 kg/m^2 • Ability to provide informed consent. • Ability to provide consent from their personal physician to participate in this study.	• Reporting regular exercise participation of at least 20 minutes per day on at least 3 days per week during the previous six months. (*This study is designed to recruit relatively sedentary adults.)* • Diabetes, hypothyroidism, or other medical conditions which would affect energy metabolism. • Women who are currently pregnant, pregnant within the previous six months, or planning on becoming pregnant within the next 18 months. (Pregnancy during initial screening will be based on self-report and will be included on the detailed medical history that is completed by subjects) • Non-medicated resting systolic blood pressure $\geq$160 mmHg or non-medicated resting diastolic blood pressure $\geq$100 mmHg, or taking medication that would affect blood pressure. • Taking medication that would affect resting heart rate or the heart rate response during exercise (e.g., beta blockade). • Arrhythmia on resting or exercise electrocardiogram that would indicate that vigorous exercise was contraindicated. • History of myocardial infarction or valvular disease. • Weight loss of >5% of body weight within the previous 12 months. • History of orthopedic complications that would prevent optimal participation in the exercise component (e.g., heel spurs, severe arthritis).

APPENDIX D

Office Use Only			
Subject ID #:		**Assessment #:**	

EXERCISE HABITS

1. Was there anything about the past week that made exercising especially different for you in terms of extended illness, injury, or vacation?

☐$_1$Yes ☐$_2$No

*If "NO", please complete this questionnaire about this past week.
*If "YES", please complete this questionnaire about the previous week.

2. First, we are interested in the number of flights of stairs you climbed on average **EACH DAY** in this past week. We only want to know the number of flights you climb going UP - not down.
One Flight = 10 steps if you know the number of steps.

______ Flights per day

3. Next, we want to know how many city blocks or their equivalent you walked on average **EACH DAY** in this past week. We are only interested in walking done out of doors and walking done indoors for the sole purpose of exercise. We do not want walking done around the house or at work.
Consider that 12 city blocks = 1 mile.

______ Blocks per day

4. Were there any sports, fitness, or recreational activities in which you participated during the past week? We are interested only in time that you were physically active.
(Note: all walking should only be included in Question 3)

Sport, Fitness, or Recreation	**Times per Week**		**Average Time per Episode**	***Office Use Only***
a.			Minutes	
b.			Minutes	
c.			Minutes	
d.			Minutes	

5. Would you say that during the past week (the week used for questions 2-4) you were:

__less active than usual

__more active than usual

__about as active as usual

6. At least once per week, do you engage in regular activity akin to brisk walking, jogging, bicycling, etc. long enough to sweat, get your heart thumping, or get out of breath?

Yes

How many times per week; Activity:

No

7. On a usual weekday and a weekend day, how much time (to the nearest 1 hour) do you spend on the following activities? ***The total for each day should add to 24 hours***

Sport, Fitness, or Recreation	**Usual Weekday Hours per Day**	**Usual Weekend Day Hours per Day**
a) Vigorous Activity digging in the garden, strenuous sports, jogging, aerobic dancing, sustained swimming, brisk walking, heavy carpentry, bicycling on hills, etc.)		
b) Moderate Activity (housework, light sports, regular walking, golf, yard work, lawn mowing, painting, repairing, light carpentry, ballroom dancing, bicycling on level ground, etc.)		
c) Light Activity (office work, driving car, strolling, personal care, standing with little motion, etc.		
d) Sitting Activity (eating, reading, desk work, watching TV, computer work, listening to the radio, etc.)		
e) Sleeping or reclining		

APPENDIX E

The 12-Week Effect of Change in Body Weight and Body Composition on Muscular Strength and Function in Overweight Adults

Subject ID #__________ Gender _____ Age _____ ☐ Baseline ☐ Follow-up

Chest Press 1-RM:

Warm-up:
▪*Women=1 plate/Men=2 plates*

________ (plates) 5-10 reps/40-60%

________ (plates) 3-5 reps/60-80%

Trials: *(If lift is successful, give 1-2 min. rest):*
▪***Circle last successfully completed lift.***

________ (plates)

________ (plates)

________ (plates)

________ (plates)

________ (plates)

▪ *Seat height (# of holes showing)* ___________

Leg Extension 1-RM:

Warm-up:
▪*Women=0 plates/Men=1 plate*

________ (plates) 5-10 reps/40-60%

________ (plates) 3-5 reps/60-80%

Trials: *(If lift is successful, give 1-2 min. rest):*
▪***Circle last successfully completed lift.***

________ (plates)

________ (plates)

________ (plates)

________ (plates)

________ (plates)

▪ *Seat height (# of holes showing)* _______

Grip Strength: Dominant hand ☐ R ☐ L

Right Hand:	**Left Hand:**
T1 __________(kg)	___________(kg)
T2 __________(kg)	___________(kg)
T3 __________(kg)	___________(kg)

▪*Grip position (measured from mid-line)*__________

Sit-to-Stand Function Test:
▪*Arms crossed at chest*

Number of stands in 30 seconds_________

Staff initials_________