

# Intensive Weight Loss Program Improves Physical Function in Older Obese Adults with Knee Osteoarthritis

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## Abstract

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**Objective:** Physical function and body composition in older obese adults with knee osteoarthritis (OA) were examined after intensive weight loss.

**Research Methods and Procedures:** Older obese adults ( $n = 87$ ;  $\geq 60$  years;  $\text{BMI} \geq 30.0 \text{ kg/m}^2$ ) with symptomatic knee OA and difficulty with daily activities were recruited for a 6-month trial. Participants were randomized into either a weight stable (WS) or weight loss (WL) program. Participants in WL (10% weight loss goal) were prescribed a 1000 kcal/d energy deficit diet with exercise 3 d/wk. WS participants attended health information sessions. Body composition and physical function (Western Ontario and McMaster University Osteoarthritis Index, 6-minute walking distance, and stair climb time) were assessed at baseline and 6 months. Statistical analysis included univariate analysis of covariance on 6-month measurements using baseline values as covariates. Associations between physical function and body composition were performed.

**Results:** Body weight decreased  $8.7 \pm 0.8\%$  in WL and  $0.0 \pm 0.7\%$  in WS. Body fat and fat-free mass were lower for WL than WS at 6 months (estimated means: fat =  $38.1 \pm 0.4\%$  vs.  $40.9 \pm 0.4\%$ , respectively; fat-free mass =  $56.7 \pm 0.4$  vs.  $58.8 \pm 0.4 \text{ kg}$ , respectively). WL had better function than WS, with lower Western Ontario and McMaster University Osteoarthritis Index scores, greater 6-minute walk distance, and faster stair climb time ( $p < 0.05$ ). Changes in function were associated with weight loss in the entire cohort.

**Discussion:** An intensive weight loss intervention incorporating energy deficit diet and exercise training improves physical function in older obese adults with knee OA. Greater improvements in function were observed in those with the most weight loss.

**Key words:** physical function, disability, meal replacements, exercise, intentional weight loss

## Introduction

According to recent national statistics from the Centers for Disease Control, 65.1% of U.S. adults are considered overweight or obese ( $\text{BMI} \geq 25.0 \text{ kg/m}^2$ ), with 26% considered obese as defined by a  $\text{BMI} \geq 30.0 \text{ kg/m}^2$  (1). The prevalence of obesity in the United States has been growing at an accelerated rate over the past two decades across all age groups, even among the elderly (2,3). For example, there was a 70% increase in obesity prevalence among 65 to 74 year olds during the past 20 years (2,3). This rise is especially troublesome in older adults, because numerous age-related health concerns are associated with excess body fat, including dyslipidemia, type 2 diabetes, hypertension, coronary heart disease, and osteoarthritis (OA),<sup>1</sup> which are all prominent in this age group (4). In particular, OA is the

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<sup>1</sup> Nonstandard abbreviations: OA, osteoarthritis; WL, weight loss; WS, weight stable; WOMAC, Western Ontario and McMaster University Osteoarthritis Index; ANCOVA, analysis of covariance; SE, standard error; IL-6, interleukin 6.

leading cause of disability in the United States (5), with the majority of those afflicted being over the age of 65 years (6,7).

Although the cause of knee OA is multifactorial, obesity is a primary risk factor (8). Cross-sectional data indicate that individuals clinically defined as obese with a BMI  $\geq 30.0$  kg/m<sup>2</sup> are four times more likely to have knee OA than those with a BMI  $\leq 25.0$  kg/m<sup>2</sup> (9). Observational evidence from the Framingham Knee OA Study shows that a reduction in weight of  $\sim 5.1$  kg decreases the risk of developing knee OA by  $>50\%$  in women with a baseline BMI  $>25.0$  kg/m<sup>2</sup> (8). In an earlier trial, we found that a moderate amount of weight loss (5% of initial weight) over the course of 18 months resulted in better self-reported physical function and decreased disability, less pain and stiffness, and faster walking speed and stair climb time compared with a weight stable control group (10). However, the magnitude of weight loss necessary to prevent the onset of OA, or that necessary to maximize improvements in function in persons with OA, is not known.

Historically, prescribing weight loss in the elderly has been controversial because of the potentially harmful effects of weight loss in accelerating the loss of lean tissue, both skeletal muscle and bone mass, which could impair physical function and independence (11). Evidence from observational cohort studies suggests that weight loss in older adults may lead to adverse outcomes (12,13), although this may be dependent on whether the weight loss is intentional or unintentional (14–17). In a recent study of obese 35 to 90 year olds with knee OA, a short-term (8 week) intensive hypocaloric diet (800 kcal/d) produced an 11% weight loss and resulted in greater improvement in self-reported physical function compared with a control group consuming 1200 kcal (4% weight loss) (18). However, this study did not focus on older adults, and there were no measures of body composition or physical performance. We found no randomized controlled trials that studied intensive weight loss exclusively in obese older adults. Therefore, the purpose of our study was to determine the effects of an intensive 6-month weight loss intervention compared with a weight stable intervention on self-report and performance task measures of physical function and body composition in older obese adults with knee OA.

## Research Methods and Procedures

### Participants

Participants ( $n = 87$ ) were recruited from the community for the Physical Activity, Inflammation, and Body Composition Trial. Recruitment was done through advertisements in newspapers, placement of brochures in clinics and physician offices, and contacting older adults who had participated in previous OA research in our facility. Eligibility criteria included: BMI  $\geq 30.0$  kg/m<sup>2</sup>,  $\geq 60$  years of age,

symptomatic knee OA, and self-reported difficulty, attributed to knee pain, in performing at least one of the following activities: lifting and carrying groceries, walking one-quarter mile, getting in and out of a chair, or going up and down stairs. Individuals were excluded if they had an unstable medical condition or condition where rapid weight loss or exercise is contraindicated (e.g., unstable angina, frailty, advanced osteoporosis). In addition, those who were unwilling to modify diet or physical activity patterns or would not be able to comply with the intervention because of food allergies or reactions to the meal replacements, those living  $>50$  miles from the treatment center, and those with known excessive alcohol consumption were excluded from the study. Initial screening for major eligibility criteria was by telephone. Eligible contacts were invited to a clinic visit for further eligibility screening, at which time all participants gave written informed consent to participate in the study according to the guidelines of the Wake Forest University Institutional Review Board.

### Design and Intervention

Participants were randomized into one of two groups: a weight stable control group (WS;  $n = 43$ ) or intensive weight loss group (WL;  $n = 44$ ).

*Intensive Weight Loss Intervention.* The weight loss goal was a 10% loss in initial body weight during the 6 months of the trial. The intervention incorporated partial meal replacements, nutrition education, and lifestyle behavior modifications. Initial diet plans for individuals in the WL group were set based on providing a daily energy deficit of 1000 kcal of dietary intake as determined by predicted energy expenditure (predicted resting metabolism  $\times 1.2$  activity factor). The lowest levels of calories provided were 1100 kcal for women and 1200 kcal for men. The calorie distribution goal for each individual was  $\sim 20\%$  from protein,  $\sim 25\%$  from fat, and  $\sim 55\%$  from carbohydrates. A maximum of two meal replacements per day (shakes and bars; SlimFast Foods Co., Englewood, NJ) were provided (see Table 1 for nutrient composition of a serving of each product) based on the participant's tolerance for the product. For the third meal, a weekly menu plan with recipes was given for participants to follow. They were free to choose the meal they preferred that allowed them to stay within the daily calorie goals. This meal of traditional foods was typically consumed in the evening, contained 500 to 750 kcal, and was low in fat and high in vegetables. Recommended snacks included fruits or vegetables providing  $\sim 100$  to 120 kcal. The food plan was tailored to allow for individual preferences for various food items.

Behavioral and educational sessions were held on a weekly basis for those in the WL group. These sessions were conducted for 60 minutes in a group ( $n = 6$  to 12 per group) and individual format and were led by a registered dietitian and exercise physiologist with expertise in behav-

**Table 1.** Macro- and micro-nutrient composition for one serving of a meal replacement used by WL in the intensive weight loss intervention

	Shake	Bar
Energy (kcal)	220	220
Macronutrient		
Protein (g)	10.0	8.0
Carbohydrates (g)	40.0	35.0
Fat (g)	2.5	5.0
Vitamins		
Vitamin A ( $\mu\text{g}$ RE)	350.0	350.0
Vitamin D (IU)	140.0	140.0
Vitamin E (IU)	30.0	10.5
Thiamin (mg)	0.5	0.5
Riboflavin (mg)	0.6	0.6
Niacin (mg)	7.0	7.0
Folate ( $\mu\text{g}$ )	120.0	120.0
Vitamin B <sub>6</sub> (mg)	0.7	0.7
Vitamin B <sub>12</sub> ( $\mu\text{g}$ )	2.1	2.1
Minerals		
Sodium (mg)	220.0	130.0
Potassium (mg)	600.0	65.0
Calcium (mg)	400.0	300.0
Phosphorus (mg)	400.0	250.0
Iron (mg)	2.7	2.7
Iodine ( $\mu\text{g}$ )	52.5	52.5
Zinc (mg)	2.3	2.3
Magnesium (mg)	140.0	140.0
Chromium ( $\mu\text{g}$ )	42.0	42.0
Selenium ( $\mu\text{g}$ )	17.5	17.5
Cholesterol (mg)	5	<5

ior therapy with older adults. All participants were instructed in behavior modification with advice on food selection, meal portion, dietary fat control, relapse prevention, and self-monitoring techniques. Throughout the duration of the study, body weight was monitored and recorded in these weekly sessions. If an individual was not meeting weight loss goals, energy intake was individually modified accordingly to produce the desired rate of weight loss. For example, a pattern of little or no weight gain resulted in further tailoring the participant's diet to further restrict calories by modifying either snacks, number of meal replacements, or the evening meal energy level. These suggestions also included behavioral techniques that emphasized the restriction of food consumption to items in their dietary plans.

All participants in the WL group were taught self-monitoring techniques for diet and body weight. They were encouraged to keep track of their intake of all foods and

beverages on a daily basis in a logbook provided to them. This information was collected by the interventionist, and participants were provided with feedback regarding their intake. This feedback occurred during the monthly individual sessions. The self-monitoring also helped design behavioral and educational strategies to aid in participants' reaching their goal weight.

Participants in WL also engaged in a structured, facility-based exercise training program 3 d/wk for 60 min/session. Individuals were instructed on techniques to promote retention in the program. The exercise program consisted of a warm-up phase (5 minutes), an aerobic phase (15 minutes), a strength phase (20 minutes), a second aerobic phase (15 minutes), and a cool-down phase (5 minutes). The primary mode of aerobic training was walking, with occasional use of cycle ergometers. The exercise intensity for the aerobic exercise portion of the training was 50% to 85% of the age-predicted heart rate reserve. In our previous studies (10,19), this program has been extremely successful regarding compliance to the intervention and preventing injuries. Participants were regularly monitored throughout the exercise program, and they recorded their heart rate during the exercise sessions. Strength training included four stations: leg extension, leg curl, heel raise, and step-ups using ankle cuff weights, weighted vest, and resistance training equipment. Two sets of 12 repetitions were performed at each station, with resistance being progressively increased during the intervention as strength improved. Lower body flexibility exercises were performed at each session.

In addition to the structured program, behavioral interventions included techniques to incorporate physical activity in the daily lives of the participants. These were emphasized on the days without the structured exercise program. Pedometers (ACCUSPLIT Eagle 120, ACCUSPLIT, Silicon Valley, CA) were distributed to the participants, and counts (steps) were recorded daily on a self-monitoring log provided to the individuals. Pedometers served as a data collection device for physical activity and as a self-monitoring tool, providing feedback to the participants. Participants were instructed to accumulate 10,000 steps/d as a goal by the end of the 6-month trial. The pedometer log was turned in to the interventionists on a weekly basis. Interventionists would review logs and provide feedback to participants based on their step totals.

*Weight Stable Intervention.* Participants randomized to this arm of the study were the attention control group and met bimonthly in a group format that included presentations on general health, including OA and exercise. Individuals were weighed at these meetings and encouraged to maintain their weight throughout the 6-month study. Bimonthly newsletters were sent to participants in months 1, 3, and 5 describing other health facts on topics such as nutrition, pertinent disease topics, aging, and other health issues in older adults. At the close of the study, individuals in the WS

control group were provided with weight loss information on diet and exercise, a 2-month supply of meal replacements and snack food provisions, a personalized exercise consultation, and 1 month of the facility-based exercise program as an incentive and reward for participation in the study.

### **Measurements**

All variables except the graded exercise test (baseline only) were collected on all participants at baseline and after the 6-month intervention.

### **Graded Exercise Test**

A graded exercise test using a symptom-limited modified Naughton protocol was performed on individuals during initial testing and was used as an exclusion criterion and to establish an individually tailored exercise prescription for eligible participants (20). A person was deemed ineligible if he/she had any of the following: 1)  $\geq 2$  mm ST-segment depression at an exercise level of four metabolic equivalents or less, 2) hypertension, or 3) complex arrhythmias.

### **Physical Function**

This variable was assessed through 1) self-report questionnaires and 2) physical performance tasks. We have used these assessments in several studies, and they are considered the measurements of choice for physical function in individuals with OA. They are relatively easy for the participant to complete.

*Self-report.* Self-reported physical function was measured using the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) (21). The WOMAC has been validated previously (21) and is recommended by the Osteoarthritis Research Society International as the measure of choice. The 24-item WOMAC instrument was developed for use in individuals who have OA of the hip or knee and is a health status instrument that assesses a participant's perception of pain (5 questions), joint stiffness (2 questions), and physical function (17 questions).

*Performance.* Physical performance tasks included the 6-minute walk distance and stair climb time. Briefly, for the first test, participants were instructed to walk as far as possible in a 6-minute time period on an established course. They were not allowed to carry a watch and were not provided with feedback during the trial. Performance was measured in the total distance covered. This test is significantly correlated to treadmill time and symptom limited maximal oxygen consumption ( $r = 0.52$  and  $r = 0.53$ , respectively) and has a 3-month test-retest reliability of 0.86 (22). The timed stair climb involved ascending and descending a flight of five stairs as quickly as possible. During the ascent, participants were instructed to grasp the handrail with their left hand, and without hesitation turn around on the platform at the top and descend using the same hand to hold the rail. Performance was measured as

the time required to complete the task. This test has a correlation value of  $r = -0.49$ , with maximal functional capacity and a test-retest reliability over a 3-month period of 0.75 to 0.87 (22).

### **Knee Pain**

Knee pain was assessed using the pain subscale of the WOMAC. The five questions in this area of the WOMAC allow participants to rate their pain from "none" to "extreme" while sitting, lying in bed, standing, walking, and ascending and descending stairs.

### **Body Weight, Height, and Waist Circumference**

These measures were obtained using standard techniques. Briefly, weight and height were determined with shoes and jackets or outer garments removed. Instruments were calibrated on a weekly basis. Waist circumference was obtained by placing a measuring tape in a horizontal plane around the abdomen at the level of the iliac crest, ensuring that the tape did not compress the skin, but was snug and parallel to the floor. The measurement was made at the end of a normal expiration.

### **Body Composition**

DXA (Hologic Delphi QDR; Hologic, Bedford, MA) was used to assess fat mass and fat-free mass. The DXA instrument emits photons at two different energy levels as a detection scanner transverses the entire body. This scanner detects the energy that has passed through the body, and a computer analyzes the differential attenuation to calculate body fat. DXA offers high precision, intra-test reproducibility, emits low radiation, and has been validated against hydrodensitometry (23,24).

### **Data Analyses**

Univariate analysis of covariance (ANCOVA) was used to compare differences between groups in follow-up measures for body weight, body composition, and physical function. The baseline value of the variable was used as the covariate in the model. Estimated marginal means are presented from the analysis. Differences were deemed significant at  $p < 0.05$ . Pearson product correlations were performed for changes in body weight and body fat (both in kilograms and percentages) with changes in physical function measures. Values for all measures are presented as means with standard error (SE). Estimated marginal means from ANCOVA are used in figures, whereas raw means are shown in tables. All analyses were performed on SPSS version 14.0 (SPSS, Inc., Chicago, IL).

## **Results**

A total of 499 individuals were screened by phone, and of these, 132 (26%) met the eligibility requirements and were

willing to schedule a screening visit. The remaining were either not interested ( $n = 123$ ) or not eligible ( $n = 244$ ). Eighty-seven of 132 (66%) were randomized. The top three reasons for failing screening were inadequate BMI ( $n = 60$ ), already participating in another research study ( $n = 33$ ), and scheduled for a knee replacement ( $n = 27$ ).

Of the 87 randomized participants, there were 8 dropouts (9% of total), and 79 individuals (91%; 41 in WL and 38 in WS) returned and completed at least partial follow-up testing. The number of participants tested for each dependent variable varies, with the  $n$  designated in the tables and/or figures depicting the results. There were no differences with regard to age, sex, body weight, BMI, or function (WOMAC sum score) at baseline assessment in the participants who completed at least partial follow-up testing vs. those who dropped out of the study. None of the participants dropped out because of direct effects or complications of the intervention. The most common reason for not completing the study and not performing all testing was that participants in the WS group wanted to be randomized to the WL group. Other explanations for dropping out included moving from area, medical condition unrelated to study intervention, transportation issues, and undisclosed personal reasons.

Baseline demographics and descriptive statistics are shown in Table 2. There were no differences between the two randomized groups for any of the variables described. The majority of the participants were women, with a mean age of 69.5 years. Nearly 70% of the cohort had at least some college education. The most common comorbidities and previous diseases were hypertension, lung disorders, arrhythmia, cancer, and diabetes.

In the WL group, participants attended an average of 77.5% of the exercise sessions over the 6-month study duration. This ranged from 83% of the sessions in Month 1 to 72% in Month 6. Overall, WL participants attended 75% of the nutrition sessions (both group and individual). These data include all participants who were randomized into the study.

### ***Anthropometrics and Body Composition***

Raw means for baseline and 6-month measures and change between measurements are shown in Table 3. At baseline, there were no group differences in body mass, BMI, waist circumference, body fat (kilogram and percent of total body), or lean body mass (Table 3). There was a significant difference in body mass between WL and WS at 6 months, with estimated means  $\pm$  SE of  $90.1 \pm 0.7$  and  $98.5 \pm 0.8$  kg, respectively ( $p < 0.01$ ; Figure 1). Mean percentage of weight loss from baseline was  $-8.7 \pm 0.8\%$  for WL and  $0.0 \pm 0.7\%$  for WS. The proportion of WL participants who obtained at least 5% weight loss at 6 months was 84%, with 50% achieving at least 10% weight loss. ANCOVA showed that estimated means for waist circumference were also different ( $p = 0.013$ ) between

**Table 2.** Baseline demographics and descriptives for all randomized participants

Variable	Weight stable ( $N = 43$ )	Weight loss ( $N = 44$ )
Age (years)	69.3 (0.9)	69.7 (0.9)
Sex		
Percent female ( $n$ )	60.5 (26)	63.6 (28)
Weight (kg)	97.5 (15.9)	98.1 (17.3)*
BMI ( $\text{kg}/\text{m}^2$ )	34.3 (3.9)	34.9 (4.9)
Race/ethnicity [% ( $n$ )]		
Asian/Pac Islanders	0	0
Hispanic	0	0
Black	14.0 (6)	9.1 (4)
White	86.0 (37)	81.8 (36)
Native American	0	4.5 (2)
Education [% ( $n$ )]		
None	0	0
High school	7.0 (3)	4.5 (2)
High school graduate	20.9 (9)	9.1 (4)
Vocational training	9.3 (4)	11.4 (5)
Some college	16.3 (7)	25.0 (11)
Associate degree	9.3 (4)	6.8 (3)
College graduate	18.6 (8)	13.6 (6)
Graduate or professional school	9.3 (4)	18.2 (8)
Masters or doctoral degree	9.4 (4)	11.4 (5)
Comorbidities [% ( $n$ )]		
Angina or chest pain	9.5 (4)	9.5 (4)
Congestive heart failure	0 (0)	0 (0)
Arrhythmia or heart surgery	21.4 (9)	16.7 (7)
Myocardial infarction	4.8 (2)	7.1 (3)
Hypertension	59.5 (25)	59.5 (25)
Cancer	19.0 (8)	21.4 (9)
Diabetes	19.0 (8)	19.0 (8)
Lung disorders	26.2 (11)	14.3 (6)
Kidney disease	2.4 (1)	7.1 (3)
Leg cramp, poor circulation	14.3 (6)	16.7 (7)
Transient ischemic attack	4.8 (2)	2.4 (1)

\*  $n = 43$  for body weight in weight loss at baseline.

groups after the intervention. Similarly, body fat was lower ( $p < 0.01$ ) for WL compared with WS (kilogram and percent) at 6 months [estimated means: fat (kilograms) =  $40.5 \pm 0.7$  for WS and  $35.0 \pm 0.7$  for WL; fat (%) =

**Table 3.** Anthropometrics and body composition measures at baseline and 6 months and their change between time-points

Variable	Weight stable	Weight loss
Body weight (kg)		
Baseline	97.5 (2.4) ( <i>n</i> = 43)	98.1 (2.6) ( <i>n</i> = 43)
6 months	98.9 (2.9) ( <i>n</i> = 33)	89.8 (2.7) ( <i>n</i> = 41)
Change	-0.1 (0.7) ( <i>n</i> = 33)	-8.3 (0.8) ( <i>n</i> = 40)
BMI (kg/m <sup>2</sup> )		
Baseline	34.3 (0.6) ( <i>n</i> = 43)	34.9 (0.7) ( <i>n</i> = 42)
6 months	34.5 (0.7) ( <i>n</i> = 31)	32.1 (0.8) ( <i>n</i> = 38)
Change	0.3 (0.9) ( <i>n</i> = 31)	-8.1 (0.7) ( <i>n</i> = 37)
Waist circumference (cm)		
Baseline	109.4 (2.2) ( <i>n</i> = 37)	110.5 (2.6) ( <i>n</i> = 38)
6 months	111.3 (2.2) ( <i>n</i> = 29)	102.5 (2.5) ( <i>n</i> = 38)
Change	-1.1 (0.9) ( <i>n</i> = 26)	-8.9 (1.7) ( <i>n</i> = 33)
Body fat (kg)		
Baseline	40.3 (1.1) ( <i>n</i> = 43)	39.8 (1.5) ( <i>n</i> = 42)
6 months	40.8 (1.3) ( <i>n</i> = 33)	34.8 (1.8) ( <i>n</i> = 39)
Change	0.0 (0.5) ( <i>n</i> = 33)	-5.4 (0.8) ( <i>n</i> = 39)
Body fat (% total body)		
Baseline	41.3 (1.0) ( <i>n</i> = 43)	40.5 (1.1) ( <i>n</i> = 42)
6 months	41.2 (1.1) ( <i>n</i> = 33)	37.9 (1.2) ( <i>n</i> = 39)
Change	-0.4 (0.7) ( <i>n</i> = 33)	-7.3 (1.1) ( <i>n</i> = 39)
Fat-free mass (kg)		
Baseline	58.0 (1.9) ( <i>n</i> = 43)	58.6 (1.9) ( <i>n</i> = 42)
6 months	59.0 (2.3) ( <i>n</i> = 33)	56.5 (1.8) ( <i>n</i> = 42)
Change	0.4 (0.4) ( <i>n</i> = 33)	-1.8 (0.4) ( <i>n</i> = 39)

Values are means (standard error) (*n*).

40.9 ± 0.4 for WS and 38.1 ± 0.4 for WL]. Lean body mass was also lower in the WL group at 6 months (*p* < 0.01), with estimated means of 58.8 ± 0.4 kg for WS and 56.6 ± 0.4 kg for WL.

In a separate analysis, only six of the completers in WL failed to lose at least 5% of their body weight (with two actually having weight gain). Attendance at exercise and nutrition sessions for these six participants was 62% compared with 81% for those with at least a 5% weight loss. Those who gained weight in WL attended only about one-half of the sessions and had personal situations that prohibited them from completing the WL intervention, although they were available for final testing. In contrast, three participants in WS had more than a 5% weight loss, although the mean weight change for WS achieved the study goal of weight stability. Additionally, 42% of those in WS maintained their weight (±2% change), with an equal number gaining or losing significant weight (>2% change).

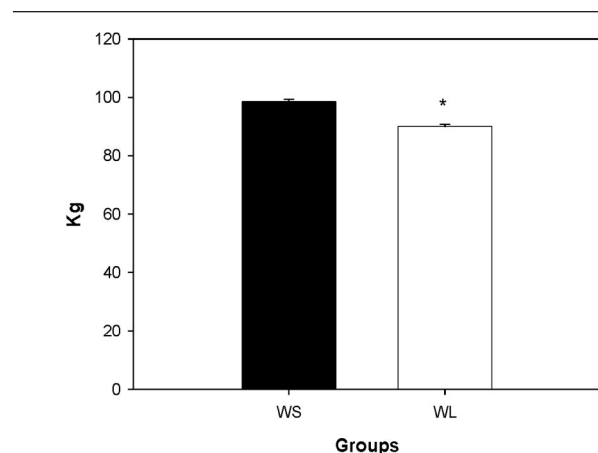


Figure 1: Comparison of 6-month body weight between groups. Estimated mean values (SE) are presented for each group. \* Significantly different between WL and WS. *n* = 33 for WS and *n* = 40 for WL.

**Table 4.** Physical function measures at baseline and 6 months and their change between time-points

Variable	Weight stable	Weight loss
WOMAC sum		
Baseline	36.6 (2.5) ( <i>n</i> = 43)	33.9 (2.0) ( <i>n</i> = 44)
6 Months	33.0 (2.6) ( <i>n</i> = 35)	22.3 (1.9) ( <i>n</i> = 39)
Change	-1.7 (2.2) ( <i>n</i> = 35)	-11.2 (2.4) ( <i>n</i> = 39)
WOMAC pain		
Baseline	6.3 (0.5) ( <i>n</i> = 43)	6.5 (0.5) ( <i>n</i> = 44)
6 Months	6.1 (0.5) ( <i>n</i> = 35)	4.1 (0.4) ( <i>n</i> = 39)
Change	0.1 (0.5) ( <i>n</i> = 35)	-2.3 (0.5) ( <i>n</i> = 39)
WOMAC stiffness		
Baseline	3.6 (0.2) ( <i>n</i> = 43)	3.3 (0.2) ( <i>n</i> = 44)
6 Months	3.1 (0.3) ( <i>n</i> = 35)	3.0 (0.2) ( <i>n</i> = 39)
Change	-0.3 (0.3) ( <i>n</i> = 35)	-0.4 (0.3) ( <i>n</i> = 39)
WOMAC function		
Baseline	26.7 (1.9) ( <i>n</i> = 43)	24.0 (1.5) ( <i>n</i> = 44)
6 Months	23.8 (2.0) ( <i>n</i> = 35)	15.2 (1.5) ( <i>n</i> = 39)
Change	-1.6 (1.6) ( <i>n</i> = 35)	-8.4 (1.8) ( <i>n</i> = 39)
6-minute walk distance (m)		
Baseline	447.8 (14.9) ( <i>n</i> = 43)	436.5 (13.0) ( <i>n</i> = 44)
6 Months	459.0 (17.4) ( <i>n</i> = 32)	510.0 (15.0) ( <i>n</i> = 39)
Change	10.5 (6.3) ( <i>n</i> = 32)	72.8 (10.3) ( <i>n</i> = 39)
Stair climb time (sec)		
Baseline	10.7 (0.8) ( <i>n</i> = 43)	9.2 (0.5) ( <i>n</i> = 44)
6 Months	11.2 (1.2) ( <i>n</i> = 33)	7.7 (0.4) ( <i>n</i> = 39)
Change	0.8 (0.5) ( <i>n</i> = 33)	-1.5 (0.5) ( <i>n</i> = 39)

Values are means (standard error). WOMAC, Western Ontario and McMaster University Osteoarthritis Index.

### Physical Function

Raw means for baseline and 6-month measures and change between measurements are shown in Table 4. There were no group differences in measures for physical function at baseline. Greater improvement in each of the physical function assessments, both self-report and physical performance tasks, were observed in WL compared with WS at 6 months. Estimated means for sum of WOMAC were  $22.6 \pm 1.9$  units for WL vs.  $32.7 \pm 2.0$  units for WS ( $p < 0.01$ ), with a lower score indicating higher function (Figure 2). In addition, all sub-measures from the WOMAC scale (pain, stiffness, and function) were different between groups at 6 months, with WL showing less pain and stiffness and higher function than WS ( $p < 0.05$ ; estimated means not shown). The WL group showed higher function compared with WS in performance tasks, with a greater walking distance at 6 months in the 6-minute walk ( $p < 0.01$ ; Figure 3) and faster time in the stair climb time ( $p < 0.01$ ). Six-month estimated means from ANCOVA for 6-minute walk distance were

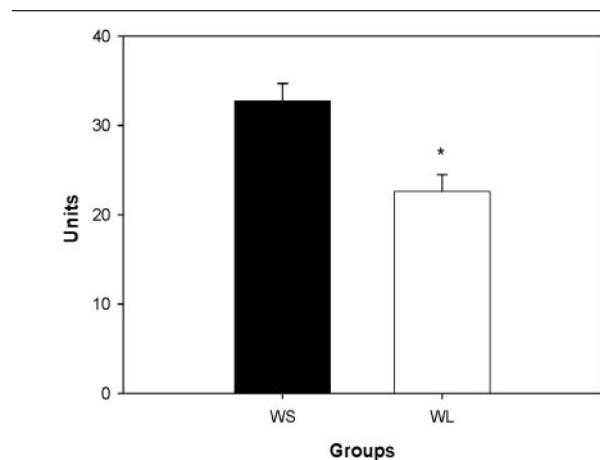


Figure 2: Comparison of 6-month WOMAC sum scores between groups. Estimated mean values (SE) are presented for each group. \* Significantly different between WL and WS. *n* = 35 for WS and *n* = 39 for WL.

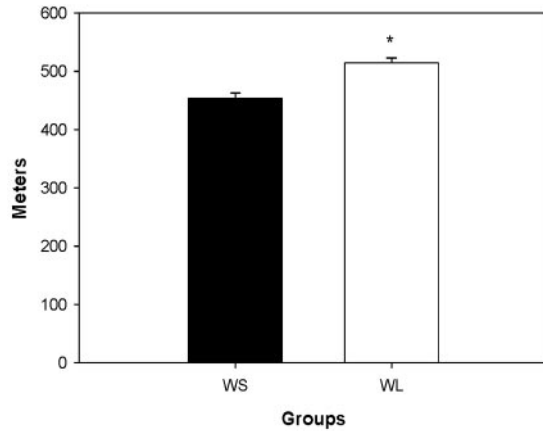


Figure 3: Comparison of 6-month 6-minute walk distance between groups. Estimated mean values (SE) are presented for each group. \* Significantly different between WL and WS.  $n = 32$  for WS and  $n = 39$  for WL.

514.6 ± 8.5 m for WL vs. 453.5 ± 9.4 m for WS. Estimated means for the stair climb time at 6 months were 8.2 ± 0.5 seconds for WL and 10.5 ± 0.5 seconds for WS.

**Relationships between Changes in Physical Function/ Performance and Changes in Body Composition**

Pearson product correlations were performed between changes in self-report and physical performance tasks with changes in body composition and body weight measures in the entire cohort, irrespective of group assignment (Table 5). Changes in all measures of function, except for WOMAC stiffness subscale, were significantly correlated ( $p < 0.05$ ) with changes in body weight (kilograms and percent) such that greater weight loss was associated with improvement in function through either lower WOMAC scores and stair climb time or greater walking distance. Interestingly, only changes in 6-minute walking distance were associated with changes in fat (kilograms and percent) and fat-free mass ( $p < 0.01$ ). As body fat decreased, distance walked increased. Also, a decrease in lean body mass was associated with greater walking distance.

**Discussion**

A moderate weight loss intervention (~5% loss) that incorporates calorie restriction +/- exercise training has previously been shown to improve physical function in older adults with knee OA (10). However, it was uncertain

**Table 5.** Correlations between changes in physical function measures with changes in body mass and body composition for all participants combined

Variables	Δ body weight (kg)	Percent Δ body weight	Δ fat mass (kg)	Percent Δ fat mass	Δ fat-free mass (kg)
Δ WOMAC sum	$r = 0.323$	0.317	0.132	0.153	-0.101
	$p = 0.008$	0.010	0.281	0.209	0.412
	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )
Δ WOMAC pain	0.346	0.339	-0.001	0.020	-0.040
	0.004	0.005	0.994	0.870	0.747
	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )
Δ WOMAC stiffness	0.204	0.205	0.024	0.057	-0.237
	0.100	0.098	0.843	0.643	0.052
	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )
Δ WOMAC function	0.310	0.307	0.156	0.170	-0.094
	0.011	0.012	0.200	0.162	0.445
	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )	( $n = 69$ )
Δ 6-minute walk distance (ft)	-0.528	-0.492	-0.352	-0.331	-0.343
	<0.001	<0.001	0.004	0.006	0.005
	( $n = 68$ )	( $n = 68$ )	( $n = 68$ )	( $n = 68$ )	( $n = 68$ )
Δ Stair climb time (sec)	0.332	0.356	0.214	0.157	0.118
	0.007	0.004	0.080	0.200	0.340
	( $n = 68$ )	( $n = 68$ )	( $n = 68$ )	( $n = 68$ )	( $n = 68$ )

Values are  $r$  and  $p$  values ( $n$ ). WOMAC, Western Ontario and McMaster University Osteoarthritis Index.

to what extent a more intensive weight loss intervention that features a more severe calorie restriction along with exercise training would affect physical function in this population, because weight loss in older adults is associated with increased morbidity and mortality. In addition, the effect that the intensive intervention has on body composition has not previously been examined. We looked at both of these issues in this study and observed that the WL group obtained a mean weight loss of 8.5% and showed higher physical function assessed by self-reported and performance tasks compared with WS controls. This improvement in function occurred despite a significant decrease in lean body mass accompanying the loss of fat mass in the WL compared with the WS group. Furthermore, correlation analysis showed that greater weight loss was associated with better improvements in function, a finding that had not been observed previously.

Although, to our knowledge, this is the first randomized control trial that studied physical function and body composition changes after a more intensive weight loss intervention exclusively in older adults, our findings are consistent with those from other populations. Christensen et al. (18) used a wide range in population age (35- to 90-year age range) of obese adults with knee OA. In their 8-week study, the percentage change in the WOMAC index was 35% for the group that lost 11% of their body weight. Their controls also lost significant weight (4.3% of body weight), with only a 15% improvement in WOMAC score. Our WL group experienced a similar level of improvement in WOMAC score (~33%) as their intensive weight loss group, although their intervention had an increased weight loss (11% vs. 8.5%) and was of shorter duration (8 weeks vs. 6 months). In our previous study examining mild weight loss and exercise, the group that lost only 5.7% of body weight improved their WOMAC physical function score by 24%, whereas the group that lost only 3.7% showed only 11% enhancement in function (10). Furthermore, Jensen et al. (16), using a single-arm study design, found that a 4% change in body weight over 3 months resulted in only a 5% improvement in function. Taken together, these findings indicate that a greater degree of weight loss (~10%) provides greater benefit to physical function.

In addition to improvement in self-reported physical function, we found that both the 6-minute walk distance and stair climb time improved to a similar degree (~17%) with intensive weight loss. This is consistent with our earlier findings that also observed close to a 15% improvement in walking and stair climbing speed with moderate weight loss (10). This comparable level of improvement with intensive and moderate weight loss suggests a possible ceiling effect for improving functional performance as measured by these tasks, at least in this population. Further weight reduction in our most recent study did not show a linear increase in these measures. It could be postulated that, whereas mild and

intensive weight loss improve performance measures, greater weight loss could lead to a higher loss of fat-free mass, thereby dampening the benefit of intensive weight loss. However, currently, we found significant relationships between amount of weight loss and physical function, with greater weight loss providing increased function. This is consistent with an earlier trial by Messier et al. (25) that produced a 9.3% weight loss in older adults with knee OA and found a 25% to 30% improvement in stair climb time and 6-minute walk distance. However, a dose-response study would need to be performed to confirm this observation, because in the severely obese, greater weight loss may be necessary to provide similar functional improvement.

This study shows that an intervention that uses partial meal replacements to induce energy restriction as part of the weight loss program can be successfully used in older adults. Participants showed good tolerance to the meal replacements (shakes and bars) as indicated by their logs and continual use during the study. The level of weight lost we observed at 6 months is consistent with that observed in a meta- and pooling analysis of meal replacement strategy for weight loss in adults (>18 years) (26). This strategy for weight loss treatment showed long-term success in earlier trials with a younger cohort and should be considered by practitioners as a viable method for safe and effective weight loss. However, the potential cost of meal replacements should be considered when determining weight loss treatment options. Meal replacements were provided to participants (up to two per day) throughout the study. It is uncertain whether the expense of specialized meals would affect the success of the intervention. For our cohort, the weight loss strategy incorporating partial meal replacements, behavior modifications with self-monitoring, and exercise training was deemed relatively successful as assessed by the number of participants who lost at least 5% of their body weight (>80% of completers) compared with <10% of WS showing similar weight loss.

Obesity increases risk for impairments in physical function (17,27-29). However, epidemiological evidence raises a concern that weight loss in older adults may be detrimental, because an increase in mortality has been shown in those having substantial weight loss (>5%) (12,13). Data from the National Health and Nutrition Education II Mortality Study showed that recent involuntary weight loss was present in >13% of 50 to 74.9 year olds, with nearly 7% of them experiencing >5% loss in body weight (30). This level of weight loss was associated with poor health and mortality, including decreased functional status and frailty (17,31,32). Furthermore, others have shown that declines in health and increased mortality have been related to both intentional and unintentional weight loss in the elderly (33). Increased levels of fat mass have been more indicative of loss of function as measured by activities of daily living than loss of fat-free mass (34,35), with the latter body

composition compartment being a less sensitive measure than skeletal muscle tissue alone. The age-related decreases in appendicular skeletal muscle, namely sarcopenia, increase the odds ratio for difficulties in activities of daily living (36). The combination of sarcopenia and obesity (sarcopenic obesity) was more associated with disability than either alone (37). There is fear that weight loss in the elderly may lead to excessive decreases in fat-free mass including appendicular skeletal muscle, thereby accelerating functional decline. Our findings do not support this notion. Not only did we observe a significant increase in function with WL compared with WS, there was a significant difference in fat-free mass, with WL having, on average, 2 kg less fat-free mass at 6 months vs. WS. We did not assess whether the difference between groups in fat-free mass was also apparent in appendicular skeletal muscle mass. Nevertheless, based on previous epidemiological evidence, it would seem advantageous to identify an intensive weight loss intervention in older adults that maximizes fat loss and minimizes skeletal muscle loss, especially in those with severe frailty. Because loss of bone mass occurs with aging, monitoring bone density in this population should receive attention, especially in individuals undergoing a long-term intensive weight loss program. Inclusion of calcium and vitamin D supplements, along with weight-bearing exercise training, would be an area for future study.

Elevated biomarkers of inflammation have been linked to age-related physical disability (38–40). It has been proposed that proinflammatory cytokines, such as interleukin 6 (IL-6) and tumor necrosis factor  $\alpha$ , may cause an acceleration of muscle catabolism, which results in sarcopenia and functional decline (41). IL-6 is a strong predictor for onset of disability (39), and both IL-6 and C-reactive protein, a stable biomarker of inflammation, are associated with mortality risk in older persons (40). We have previously shown that dietary-induced weight loss reduces proinflammatory markers, including IL-6, C-reactive protein, and tumor necrosis factor  $\alpha$  soluble receptor 1, in older adults with knee OA (42). However, there was no effect of exercise training on inflammation. It would be of interest to examine the effect of the intensive weight loss intervention on proinflammatory biomarkers in this population. This may be a probable mechanism for the improvement in physical function observed in this study.

This study is limited in interpretation based on several factors. The population targeted for this study was older obese adults with knee OA. However, evidence for knee OA was based on subjects reporting that their physician had diagnosed them with knee OA and from current symptoms, but not radiographic evidence. In addition, the study sample was highly selective, with most being well educated and with no Mexican Americans and few African Americans included in the study. Participants were not excluded based on demographics. The ability to generalize these findings is

limited because of the narrow scope of the population studied and the unwillingness of older adults to invest in meal replacements.

The recent documentation of serious cardiovascular effects from pharmacological interventions aimed at relieving pain and inflammation, namely use of cyclooxygenase-2 inhibitors, brings to the forefront the need to develop safe and effective behavioral lifestyle treatments for OA. There were no adverse, or at least no serious adverse, events attributed to the weight loss intervention during our study. Substantial improvements in physical function and pain measured by self-report and performance tasks suggest that incorporating weight loss with exercise training is an effective alternative to medications. A weight loss strategy using partial meal replacements along with exercise training improved self-reported function and pain by 33% and physical performance by 15%, with significant reductions in body fat. Lastly, correlation data suggest that greater weight loss may lead to further improvements in function in older obese adults with knee OA.

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