See corresponding editorial on page 1257.

Effect of lifestyle intervention on metabolic coronary heart disease risk factors in obese older adults[1–3]

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ABSTRACT

Background: Coronary heart disease (CHD) risk factors increase with age and body mass index (BMI; in kg/m^2). However, whether lifestyle intervention ameliorates metabolic CHD risk factors in obese older adults is unknown.

Objective: The objective was to determine whether lifestyle intervention improves metabolic CHD risk factors in obese older adults.

Design: A 6-mo outpatient randomized controlled trial was conducted in obese (BMI ≥ 30) older (≥65 y) adults randomly assigned to diet and exercise therapy (treatment group; $n = 17$) or no therapy (control group; $n = 10$). The main outcomes were CHD risk factors.

Results: Body weight decreased by 8.4% (8.2 kg) in the treatment group; weight did not change significantly (0.7 kg) in the control group ($P < 0.001$ between groups). Changes between the control and treatment groups, respectively, in waist circumference (1 and −10 cm), plasma glucose (4 and −4 mg/dL), serum triacylglycerols (0 and −45 mg/dL), and systolic (−2 and −10 mm Hg) and diastolic (0 and −8 mm Hg) blood pressure were different ($P < 0.05$ for all). The number of subjects with the metabolic syndrome decreased by 59% in the treatment group but did not change significantly in the control group ($P < 0.05$). Serum free fatty acids increased by 10 μmol/L in the control group and decreased by 99 μmol/L in the treatment group ($P < 0.05$). Changes between the control and treatment groups, respectively, in C-reactive protein (0.8 and −2.5 mg/L) and interleukin 6 (1.6 and −2.4 pg/mL) were different ($P < 0.05$ for both).

Conclusions: Lifestyle intervention decreases multiple metabolic CHD risk factors simultaneously in obese older adults. *Am J Clin Nutr* 2006;84:1317–23.

KEY WORDS Aging, obesity, metabolic syndrome, lifestyle intervention, atherosclerosis

INTRODUCTION

Coronary heart disease (CHD) is an important cause of mortality in older adults (age ≥ 65 y) (1). It is estimated that 60–65% of myocardial infarctions occur in patients aged ≥65 y, and 33% occur in patients aged ≥75 y (2, 3). Many CHD risk factors (eg, high blood glucose concentration, hypertension, abnormal blood lipid concentration, and abdominal obesity) increase in prevalence and severity with age. The conventional metabolic CHD risk factors, such as hypertension, hyperlipidemia, and diabetes, remain powerful predictors of cardiac events in older adults (4, 5). Other metabolic variables, such as elevated plasma concentrations of free fatty acids (FFAs) and inflammatory markers (eg, C-reactive protein), are also independent risk factors for CHD in middle-aged and older adults (6–8). Moreover, the coexistence of multiple metabolic CHD risk factors is more common in older adults than in young and middle-aged adults. The metabolic syndrome represents a constellation of abnormalities that are associated with an increased risk of type 2 diabetes and CHD (9). The prevalence of the metabolic syndrome, as defined by the National Cholesterol Education Program's Adult Treatment Panel III (NCEP ATP III) (10), increases with increasing age. Data from the third National Health and Nutrition Examination Survey (NHANES III) found that ≈42% of persons aged ≥65 y had the metabolic syndrome (11, 12).

Lifestyle intervention is recommended as the cornerstone of therapy for obese persons who have metabolic risk factors for CHD (10, 13, 14). Diet-induced weight loss and increased physical activity improve obesity-related metabolic abnormalities in young and middle-aged adults (14, 15). However, weight-loss therapy in obese older adults is controversial because the relative health risks associated with increasing body mass index (BMI; in kg/m^2) decrease and the BMI value associated with the lowest mortality rate increases with increasing age (16–18). In addition, many obese older persons meet criteria for frailty (19, 20), which can make it difficult to implement lifestyle changes.

The purpose of this study was to evaluate the combined effect of diet-induced weight loss and exercise on metabolic CHD risk factors in obese older adults. We hypothesized that this lifestyle intervention would simultaneously improve multiple metabolic risk factors for CHD, including waist circumference, blood pressure, serum lipid profile, plasma glucose and FFA concentrations, insulin sensitivity, plasma inflammatory markers, and a diagnosis of the metabolic syndrome.

SUBJECTS AND METHODS

Subjects

A total of 27 obese (BMI ≥ 30) older (age ≥ 65 y) men and women were enrolled in this study. All subjects had evidence of

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[2] Supported by grants AG025501, AG2116401, AG00078, DK37948, DK020579, RR00036, RR016191, and DK56341 from the National Institutes of Health and by a grant from the Longer Life Foundation.

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Received June 15, 2006.

Accepted for publication June 20, 2006.

mild-to-moderate physical frailty on the basis of meeting ≥2 of the following 3 criteria: *1*) modified physical performance test score of 18–32, *2*) peak oxygen consumption ($\dot{V}O_{2peak}$) of 11–18 $mL \cdot min^{-1} \cdot kg\ body\ wt^{-1}$, and *3*) self-reported difficulty or need for assistance in performing 2 instrumental activities of daily living (ADL) or 1 basic ADL (19, 21, 22). The physical performance test has a perfect total test score of 36; it includes 7 timed tests [walking 50 ft (1524 cm), putting on a coat, picking up a penny, standing up from a chair, lifting a book, climbing a flight of stairs, and standing with both feet in different positions] and 2 tasks (performing a 360 ° turn and climbing up and down 4 flights of stairs) (19). The effect of diet and exercise therapy on physical function and body composition in these subjects was recently reported (21).

All subjects completed a comprehensive medical evaluation, including a medical history, physical examination, standard blood and urine tests, and a graded treadmill exercise stress test. The subjects were sedentary (ie, did not participate in regular exercise more than twice a week) and reported having had a stable body weight (±2 kg) for ≥1 y before the study. In addition, no subjects had any changes in medication use for ≥6 mo before starting the study. The subjects with severe or unstable cardiopulmonary disease, history of diabetes, history of malignancy during the past 5 y, musculoskeletal impairment that precluded exercise training, and recent use of corticosteroids, androgens, or estrogen-containing compounds were excluded from participating in this study.

This study was approved by the Human Studies Committee and the General Clinical Research Center Scientific Advisory Committee at Washington University School of Medicine. All subjects provided written informed consent before his or her participation.

Study design

The subjects were randomly assigned to 26 wk of treatment with a low-calorie diet and exercise training (treatment group; $n = 17$) or no treatment (control group; $n = 10$) in a ratio of ≈1.5:1 by using a computer-generated block random permutation procedure stratified for sex (23). The subjects who were randomly assigned to diet plus exercise participated in weekly behavioral therapy group meetings at the Washington University Weight Management Center and in a supervised exercise-training program (90-min sessions, 3 d/wk) at the Exercise Physiology Laboratory in the Center for Human Nutrition.

Control group intervention

Subjects assigned to the control group were instructed to maintain their usual diet and activities during the study period. These subjects were advised not to participate in any weight-loss or exercise program and had minimal contact with our research team while participating in the study.

Treatment group intervention

Each participant was prescribed a balanced diet to provide an energy deficit of ≈750 kcal/d. Daily energy requirement was determined by estimating resting energy expenditure and multiplying the obtained value by 1.3 (24). The diet contained ≈30% of energy as fat, 50% as carbohydrate, and 20% as protein. Total calorie intake was adjusted to prevent more than a 1.5% loss of body weight per week, with the goal of 10% weight loss at the completion of the study. Participants were instructed to take a multivitamin supplement daily.

Subjects met weekly as a group with a study dietitian, who was experienced in group behavioral therapy for obesity. Standard behavioral strategies, including goal setting, self-monitoring, stimulus control techniques, problem-solving skills, identification of high-risk situations, and relapse prevention training, were used to modify eating habits.

The subjects participated in exercise-training sessions on 3 nonconsecutive days each week at our indoor exercise facility as a group. Each session was supervised by a physical therapist. The exercise program focused on improving flexibility, endurance, strength, and balance. Each session lasted 90 min and began with a 15-min warm-up of flexibility exercises, followed by 30 min of endurance exercise (≈70% of $\dot{V}O_{2peak}$), 30 min of strength training (≈80% of 1 repetition maximum), and 15 min of balance exercises.

Assessments

All assessments were performed at baseline and after 26 wk in the treatment and control groups.

Waist circumference

The anterior superior iliac crest and the lowest portion of the 12th rib were identified with subjects in the standing position. A tape measure was then placed around the subjects' bare abdomen halfway between the bony landmarks and parallel to the floor, making sure that the tape was snug but not compressing the skin during exhalation.

Blood pressure

The subjects remained in the supine position for 15 min with a deflated sphygmomanometer cuff of the appropriate size. Cuff size was determined by measuring the circumference of the arm at half the length of the humerus. Blood pressure was measured manually and recorded to the nearest 2 mm Hg. The measurement was repeated twice, and the 3 values were averaged for the final reading. Hypertension was also an inclusion criterion for the metabolic syndrome if a subject entered the study taking antihypertensive medication and had normal blood pressure readings.

Serum lipids, free fatty acids, and inflammatory markers

Blood samples were obtained in the fasting state for the measurement of serum total cholesterol, LDL cholesterol, HDL cholesterol, triacylglycerols, and FFAs. Cholesterol and glycerol-blanked triacylglycerols were measured by automated enzymatic commercial kits (Miles/Technicon, Tarrytown, NY). HDL cholesterol was measured in plasma after precipitation of apolipoprotein B–containing lipoproteins by dextran sulfate (50 000 molecular weight) and magnesium (25). These methods were continuously standardized by the Lipid Standardization Program of the Centers for Disease Control and Prevention. LDL cholesterol was calculated with the Friedewald equation (26). FFAs were measured by using an enzymatic colorimetric method (Wako Chemicals, Richmond, VA). Serum C-reactive protein (American Laboratory Products Company, Windham, NH), interleukin 6, and tumor necrosis factor α (Quantikine High Sensitivity kit; R & D Systems, Minneapolis, MN) were measured by using an enzyme-linked immunoabsorbent assay. The CVs of these assays were all <10%.

Oral-glucose-tolerance test

A standard 75-g oral-glucose-tolerance test (OGTT) was performed after an overnight fast. Venous blood samples were obtained in the fasted state and 30, 60, 90, and 120 min after glucose ingestion for the measurement of plasma glucose (glucose oxidase method) and insulin (27) concentrations. The areas under the curve (AUC) for glucose and insulin were calculated by using the trapezoid method (28). An insulin sensitivity index (29) was calculated by using the following formula:

$$\text{Insulin sensitivity index} = 10\,000/\sqrt{[(\text{fasting glucose} \times \text{fasting insulin}) \times (\text{mean glucose} \times \text{mean insulin during OGTT})]}$$

This index correlated ($r = 0.73$) with the rate of whole-body glucose disposal during a euglycemic insulin clamp study (29). Homeostasis model assessment of insulin resistance (HOMA-IR) was calculated as fasting glucose (mg/dL) multiplied by fasting insulin (μU/mL) divided by 22.5 (30).

Metabolic syndrome criteria

The presence of the metabolic syndrome was determined on the basis of the NCEP ATP III criteria (10). Accordingly, subjects who met ≥3 of the following criteria were defined as having the metabolic syndrome: abdominal obesity (waist circumference >102 cm in men and >88 cm in women), a high fasting glucose concentration (≥110 mg/dL), hypertriglyceridemia (triacylglycerol concentration ≥150 mg/dL), a low HDL-cholesterol concentration (<40 mg/dL in men and <50 mg/dL in women), and high blood pressure [≥130 (systolic)/85 (diastolic) mm Hg].

Body composition

Fat mass and fat-free mass were measured by using dual-energy X-ray absorptiometry (Delphi 4500-W; Hologic Inc, Waltham, MA), as previously reported (21).

Statistical analysis

The effect of the intervention was evaluated by using an intention-to-treat analysis. When follow-up data were not available, the last observation was carried forward. Baseline characteristics between groups were compared by using a Student's *t* test for unpaired samples for continuous variables and a chi-square test for categorical variables where appropriate. An analysis of variance (ANOVA) was used to determine whether the changes in the outcomes in the intervention group were significantly different from those in the control group. Age and baseline values were included as covariates in the ANOVA. Student's *t* tests for paired samples were performed to determine whether there were significant within-group changes in the outcomes. Study subjects were also classified as having 3, 4, or 5 components of the metabolic syndrome; a chi-square test was used to compare proportions of participants with the metabolic syndrome before and after treatment. SPSS version 14.0 (SPSS Inc, Chicago, IL) was used for all statistical analyses. A P value ≤ 0.05 was considered to be statistically significant. The results are reported as means ± SDs.

TABLE 1
Baseline characteristics of the study participants

Characteristic	Control group ($n = 10$)	Treatment group ($n = 17$)	P^1
Age (y)	71 ± 4[2]	69 ± 5	0.37
Women [*n* (%)]	6 (60)	12 (71)	0.57
White race [*n* (%)]	9 (90)	14 (83)	0.83
Height (cm)	151 ± 20	155 ± 30	0.70
Weight (kg)	103 ± 20	100 ± 14	0.61
BMI (kg/m^2)	39 ± 5	39 ± 5	0.81
Fat mass (kg)	48 ± 9	43 ± 8	0.77
Fat-free mass (kg)	56 ± 13	57 ± 11	0.17
Physical performance test score	30 ± 2	29 ± 2	0.61

[1] Data were analyzed by using Student's *t* test for unpaired samples for continuous variables and chi-square test for categorical variables.
[2] $\bar{x}$ ± SD (all such values).

RESULTS

Of the 27 obese older women and men enrolled, 24 successfully completed the study. Two subjects in the treatment group who were not compliant with the intervention dropped out of the study; one subject in the control group did not return for follow-up. These 3 subjects did not differ significantly in age and BMI from those who completed the study.

No significant differences were observed in baseline demographic characteristics or in baseline CHD risk factors between the treatment and control groups (**Tables 1–4**). The metabolic syndrome was present in 9 of the 10 subjects (90%) in the control group and in 15 of the 17 subjects (88%) in the treatment group.

At 26 wk, the treatment group lost 8.4 ± 5.6% (−8.2 ± 5.7 kg) of their body weight, whereas body weight did not change significantly in the control group (0.7 ± 2.7 kg; $P < 0.001$). Treatment decreased the prevalence of the metabolic syndrome by 59% (from 15 of 17 subjects at baseline to 5 of 17 subjects at 26 wk) and improved all criteria of the metabolic syndrome, with the exception of serum HDL-cholesterol concentration, which did not change significantly (Table 2). No change in the prevalence of the metabolic syndrome or in the individual features of the metabolic syndrome was observed in the control group.

Both glucose and insulin AUCs decreased in the treatment group but increased in the control group (Table 3). No significant within-group change in the glucose AUC was observed in the treatment group; however, a significant decrease was observed in the insulin AUC. The insulin sensitivity index and HOMA-IR also improved in the treatment group but not in the control group.

Serum LDL cholesterol did not change significantly in either the treatment or the control group (Table 4). Plasma FFA, CRP, and interleukin 6 concentrations decreased significantly in the treatment group but not in the control group.

Fat mass decreased (−6.6 ± 3.4 compared with 1.7 ± 4.1 kg; $P < 0.001$), without a change in fat-free mass (−1.2 ± 2.1 compared with −1.0 ± 3.5 kg; $P = 0.75$) in the treatment group, whereas body composition did not change significantly in the control group, as previously reported (21).

No adverse effects of the intervention were observed on serum electrolyte concentrations, liver biochemistries, or renal function tests (**Table 5**).

TABLE 2
Effect of lifestyle intervention on coronary heart disease risk factors associated with the metabolic syndrome in obese older adults[1]

	Control group (n = 10)	Treatment group (n = 17)	Difference between groups[2]	
			$\bar{x}$ (95% CI)	P
Waist circumference				
Baseline (cm)	115 ± 16[3]	115 ± 15	—	—
Final (cm)	116 ± 17	105 ± 12[4]	—	—
Percentage change (%)	1 ± 7	−8 ± 8	—	—
Absolute change (cm)	1 ± 8	−10 ± 10	−11 (−18 to −2)	<0.05
Plasma glucose				
Baseline (mg/dL)	99 ± 10	100 ± 10	—	—
Final (mg/dL)	104 ± 9	95 ± 10[4]	—	—
Percentage change (%)	5 ± 12	−4 ± 7	—	—
Absolute change (mg/dL)	4 ± 11	−4 ± 7	−8 (−17 to −4)	<0.01
HDL cholesterol				
Baseline (mg/dL)	43 ± 5	48 ± 9	—	—
Final (mg/dL)	42 ± 5	47 ± 9	—	—
Percentage change (%)	−2 ± 12	−2 ± 8	—	—
Absolute change (mg/dL)	−1 ± 2	−1 ± 4	0 (−2 to 3)	0.81
Triacylglycerol				
Baseline (mg/dL)	133 ± 39	180 ± 87	—	—
Final (mg/dL)	133 ± 60	135 ± 55[4]	—	—
Percentage change (%)	−1 ± 21	19 ± 25	—	—
Absolute change (mg/dL)	0 ± 36	−45 ± 63	−45 (−90 to 0)	<0.05
Systolic blood pressure				
Baseline (mm Hg)	139 ± 10	139 ± 9	—	—
Final (mm Hg)	136 ± 11	126 ± 8[5]	—	—
Percentage change (%)	−2 ± 3	−10 ± 6	—	—
Absolute change (mm Hg)	−3 ± 11	14 ± 9	−10 (−17 to −4)	<0.01
Diastolic blood pressure				
Baseline (mm Hg)	78 ± 4	79 ± 8	—	—
Final (mm Hg)	78 ± 4	72 ± 8[6]	—	—
Percentage change (%)	0 ± 9	−8 ± 8	—	—
Absolute change (mm Hg)	−1 ± 7	−7 ± 7	−6 (−11 to −1)	<0.05
Subjects with metabolic syndrome (n)				
Baseline				
3 criteria	6	8	—	
4 criteria	3	4	—	0.55
5 criteria	0	3	—	
Total	9	15	—	
Final				
3 criteria	6	3	—	
4 criteria	3	2	—	<0.05
5 criteria	0	0	—	
Total	9	5	—	

[1] To convert glucose to mmol/L, multiply by 0.0555; HDL cholesterol to mmol/L, multiply by 0.0259; and triacylglycerol to mmol/L, multiply by 0.0113.
[2] ANOVA was used to determine whether changes in outcomes were significantly different between groups. Age and baseline values were included as covariates. There were no significant differences in baseline values. Chi-square test was used to compare proportions of participants with the metabolic syndrome before and after treatment.
[3] $\bar{x}$ ± SD (all such values).
[4–6] Significantly different from corresponding baseline value (Student's t test for paired samples): [4]$P < 0.05$, [5]$P < 0.001$, [6]$P < 0.01$.

DISCUSSION

The marked increase in the prevalence of obesity in older adults (31) is an important contributor to the increase in multiple metabolic CHD risk factors, including the metabolic syndrome (11), that occurs with aging. The present study is the first randomized controlled trial to examine the effects of lifestyle intervention (diet and exercise therapy) on CHD risk factors in obese older persons. Our findings showed that diet-induced weight loss and exercise training improved almost all of the obesity-related metabolic CHD risk factors simultaneously, including waist circumference, blood pressure, circulating inflammatory markers, oral glucose tolerance, insulin resistance, and plasma glucose, triacylglycerol, and FFA concentrations. Therefore, these data demonstrate that long-term CHD risk factors are reversible in obese older adults; lifestyle therapy can improve or normalize the metabolic risks of CHD in older adults, as has been shown in young and middle-aged adults (14, 15).

TABLE 3
Effects of lifestyle intervention on oral-glucose-tolerance variables in obese older adults[1]

	Control group (n = 10)	Treatment group (n = 17)	Difference between groups[2]	
			$\bar{x}$ (95% CI)	P
Glucose AUC				
Baseline ($\times 10^3$ min · mg/dL)	13.8 ± 2.4[3]	14.4 ± 2.1	—	—
Final ($\times 10^3$ min · mg/dL)	14.6 ± 2.1	13.8 ± 2.2	—	—
Percentage change (%)	7 ± 16	−3 ± 10	—	—
Absolute change ($\times 10^3$ min · mg/dL)	0.7 ± 0.2	−0.6 ± 0.2	−1.3 (−2.9 to 0.3)	<0.05
Insulin AUC				
Baseline ($\times 10^3$ min · μU/mL)	6.1 ± 2.6	7.2 ± 2.7	—	—
Final ($\times 10^3$ min · μU/mL)	6.4 ± 3.9	5.3 ± 2.1[4]	—	—
Percentage change (%)	8 ± 45	−17 ± 28	—	—
Absolute change ($\times 10^3$ min · μU/mL)	0.2 ± 0.2	−1.9 ± 2.6	−2.2 (−4.7 to −0.5)	<0.01
Insulin sensitivity index[5]				
Baseline	3.5 ± 1.6	3.3 ± 1.9	—	—
Final	3.7 ± 1.9	5.2 ± 2.4[6]	—	—
Percentage change (%)	5 ± 40	66 ± 87	—	—
Absolute change	0.2 ± 1.5	1.9 ± 1.5	1.7 (0.4 to 3.2)	<0.05
HOMA-IR				
Baseline	3.1 ± 1.5	3.9 ± 2.4	—	—
Final	3.6 ± 2.6	2.6 ± 2.3[7]	—	—
Percentage change (%)	25 ± 95	−32 ± 30	—	—
Absolute change	0.4 ± 2.8	−1.3 ± 1.3	−1.7 (−3.4 to −0.1)	<0.05

[1] AUC, area under the curve; HOMA-IR, homeostasis model assessment of insulin resistance. To convert glucose to mmol/L, multiply by 0.0555, and insulin to pmol/L, multiply by 7.175.
[2] ANOVA was used to determine whether changes in outcomes were significantly different between groups. Age and baseline values were included as covariates. There were no significant differences in baseline values.
[3] $\bar{x}$ ± SD (all such values).
[4,6,7] Significantly different from corresponding baseline value (Student's t test for paired samples): [4]$P < 0.05$, [6]$P < 0.001$, [7]$P < 0.01$.
[5] Calculated as 10 000 / $\sqrt{[(\text{fasting glucose} \times \text{fasting insulin}) \times (\text{mean glucose} \times \text{mean insulin during the oral-glucose-tolerance test})]}$.

TABLE 4
Effects of lifestyle intervention on other metabolic coronary heart disease risk factors in obese older adults[1]

	Control group (n = 10)	Treatment group (n = 17)	Difference between groups[2]	
			$\bar{x}$ (95% CI)	P
LDL cholesterol				
Baseline (mg/dL)	119 ± 21[3]	110 ± 33	—	—
Final (mg/dL)	123 ± 27	104 ± 25	—	—
Percentage change (%)	3 ± 14	−2 ± 21	—	—
Absolute change (mg/dL)	4 ± 30	−5 ± 22	−9 (−26 to −7)	0.26
Free fatty acids				
Baseline (μmol/L)	785 ± 173	859 ± 152	—	—
Final (μmol/L)	795 ± 192	761 ± 122[4]	—	—
Percentage change (%)	2 ± 15	−10 ± 18	—	—
Absolute change (μmol/L)	10 ± 114	−99 ± 161	−109 (−232 to −14)	<0.05
C-reactive protein				
Baseline (mg/L)	5.8 ± 4.5	6.1 ± 5.4	—	—
Final (mg/L)	6.6 ± 4.5	3.5 ± 3.6[4]	—	—
Percentage change (%)	14 ± 29	−34 ± 29	—	—
Absolute change (mg/L)	0.8 ± 2.8	−2.5 ± 4.3	−3.3 (−6.4 to −0.2)	<0.01
Interleukin 6				
Baseline (pg/mL)	3.3 ± 1.6	4.6 ± 4.5	—	—
Final (pg/mL)	4.8 ± 4.1	2.3 ± 1.2[5]	—	—
Percentage change (%)	48 ± 72	−30 ± 31	—	—
Absolute change (pg/mL)	1.6 ± 4.3	−2.4 ± 4.7	−4.0 (−7.7 to −0.3)	<0.001

[1] To convert LDL cholesterol to mmol/L, multiply by 0.0259.
[2] ANOVA was used to determine whether changes in outcomes were significantly different between groups. Age and baseline values were included as covariates. There were no significant differences in baseline values.
[3] $\bar{x}$ ± SD (all such values).
[4,5] Significantly different from corresponding baseline value (Student's t test for paired samples): [4]$p < 0.05$, [5]$P = 0.05$.

TABLE 5
Effects of lifestyle intervention on results of liver and renal function tests in obese older adults[1]

	Control group (n = 10)	Treatment group (n = 17)	Difference between groups[2]	
			$\bar{x}$ (95% CI)	P
Alanine aminotransferase				
Baseline (U/L)	18.0 ± 6.0[3]	25.4 ± 11.3	—	—
Final (U/L)	19.8 ± 5.3	24.0 ± 7.5	—	—
Percentage change (%)	13.0 ± 26.0	4.7 ± 36.2	—	—
Absolute change (U/L)	1.8 ± 2.9	−1.4 ± 10.9	3.2 (−4.6 to 10.8)	0.43
Aspartate aminotransferase				
Baseline (U/L)	24.8 ± 7.9	26.6 ± 6.1	—	—
Final (U/L)	23.8 ± 5.6	26.4 ± 4.9	—	—
Percentage change (%)	2.7 ± 35.9	4.5 ± 30.9	—	—
Absolute change (U/L)	−1.0 ± 9.7	−0.2 ± 8.3	−0.9 (−3.7 to 6.7)	0.83
Alkaline phosphatase				
Baseline (U/L)	78.8 ± 23.2	79.8 ± 20.5	—	—
Final (U/L)	77.4 ± 22.1	81.1 ± 24.2	—	—
Percentage change (%)	−0.2 ± 17.9	4.4 ± 26.2	—	—
Absolute change (U/L)	−1.3 ± 14.1	1.3 ± 22.1	−2.6 (−19.5 to 6.7)	0.76
Blood urea nitrogen				
Baseline (mg/dL)	19.8 ± 7.1	16.8 ± 5.1	—	—
Final (mg/dL)	20.9 ± 4.9	17.9 ± 4.4	—	—
Percentage change (%)	15.9 ± 40.4	12.9 ± 33	—	—
Absolute change (mg/dL)	1.1 ± 6.0	1.1 ± 5.0	−0.0 (−4.6 to 4.6)	1.0
Creatinine				
Baseline (mg/dL)	1.0 ± 0.2	1.0 ± 0.3	—	—
Final (mg/dL)	0.9 ± 0.3	0.9 ± 0.3	—	—
Percentage change (%)	−6.4 ± 26.4	−0.2 ± 27.2	—	—
Absolute change (mg/dL)	−0.1 ± 0.3	0.0 ± 0.2	−0.1 (−0.2 to 0.1)	0.58

[1] To convert blood urea nitrogen to mmol/L, multiply by 0.0357, and creatinine to mmol/L, multiply by 0.0763.
[2] ANOVA was used to determine whether changes in outcomes were significantly different between groups. Age and baseline values were included as covariates. There were no significant differences in baseline values.
[3] $\bar{x}$ ± SD (all such values).

The findings from the present study show that lifestyle intervention with a weight-reducing diet and regular exercise ameliorates almost all metabolic CHD risk factors in obese older adults. These findings have important economic implications, because the presence of metabolic risk factors for CHD in older adults increases medical care costs (32). The increasing prevalence of obesity in older Americans and the increasing prevalence of obesity-related complications with aging are expected to challenge existing healthcare delivery and financing systems (33). In fact, the per capita increase in obesity-attributable spending is greater for Medicare recipients than for younger age groups (34), and it is estimated that the number of new obese Medicare-eligible adults will increase by 400 000 per year up to at least the year 2010 (33). Therefore, ameliorating the metabolic CHD risk factors by implementing lifestyle therapy should decrease the costs of medical therapy, hospitalization, and chronic care in obese older adults.

Approximately 90% of our study subjects had the metabolic syndrome, as defined by criteria proposed by the NCEP ATP III (10). Although the prevalence of the metabolic syndrome increases with increasing age, the prevalence in our subjects was higher than the national average of 43% reported in those aged ≥65 y (11, 12). It is likely that specifically selecting subjects who were obese and inactive, which increased the risk of having metabolic CHD risk factors (11), was responsible for the high prevalence of metabolic syndrome abnormalities. These data underscore the adverse additive effects of obesity and advanced age on metabolic health.

Both obesity and advanced age are associated with noninfectious inflammation (35, 36). Moderate weight loss induced by diet and exercise therapy decreased serum markers of inflammation, CRP and interleukin 6 in our elderly subjects, as was found previously in younger adults (37, 38). Therefore, lifestyle therapy could have important clinical implications in older adults, because increased inflammation is likely involved in the pathogenesis of cardiovascular disease, insulin resistance and type 2 diabetes, dementia, sarcopenia, and osteoporosis (7, 36, 39, 40).

We found that most of our subjects randomly assigned to treatment were very compliant with the lifestyle intervention program. The average weight loss at 26 wk in our elderly subjects (≈9% of initial body weight) was similar to the weight loss reported from other studies that involved comprehensive lifestyle therapy in young and middle- aged adults (41). These results refute the notion that it is difficult to achieve successful lifestyle-induced weight loss in older persons because of lifelong diet and activity habits (18). However, because the duration of our study was only 6 mo, additional studies are needed to evaluate the long-term efficacy and effectiveness of lifestyle intervention on body weight and clinical outcomes in obese older subjects.

In conclusion, moderate weight loss and regular exercise have considerable beneficial effects on multiple CHD risk factors

simultaneously in obese older adults. Therefore, lifestyle intervention therapy in obese older persons can reduce the risk of obesity-related medical complications, and presumably medical care costs, and improve physical function and quality of life, as shown in a previous study (21). However, additional longer-term studies are needed to determine whether the beneficial effects of lifestyle intervention therapy on CHD translate into a delay or decrease in the incidence of CHD events and increased survival.

DTV, DRS, and SK designed the study. DTV, MB, DRS, and SK performed and supervised the data collection. DTV, BVM, LF, and SK analyzed and interpreted the data. DTV, BVM, LF, DRS, and SK wrote the manuscript. None of the authors had a conflict of interest.

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