Effects of Diet and Physical Activity Interventions on Weight Loss and Cardiometabolic Risk Factors in Severely Obese Adults

A Randomized Trial

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Context The prevalence of severe obesity is increasing markedly, as is prevalence of comorbid conditions such as hypertension and type 2 diabetes mellitus; however, apart from bariatric surgery and pharmacotherapy, few clinical trials have evaluated the treatment of severe obesity.

Objective To determine the efficacy of a weight loss and physical activity intervention on the adverse health risks of severe obesity.

Design, Setting, and Participants Single-blind randomized trial conducted from February 2007 through April 2010 at the University of Pittsburgh. Participants were 130 (37% African American) severely obese (class II or III) adult participants without diabetes recruited from the community.

Interventions One-year intensive lifestyle intervention consisting of diet and physical activity. One group (initial physical activity) was randomized to diet and physical activity for the entire 12 months; the other group (delayed physical activity) had the identical dietary intervention but with physical activity delayed for 6 months.

Main Outcome Measures Changes in weight. Secondary outcomes were additional components comprising cardiometabolic risk, including waist circumference, abdominal adipose tissue, and hepatic fat content.

Results Of 130 participants randomized, 101 (78%) completed the 12-month follow-up assessments. Although both intervention groups lost a significant amount of weight at 6 months, the initial-activity group lost significantly more weight in the first 6 months compared with the delayed-activity group (10.9 kg [95% confidence interval (CI), 9.1-12.7] vs 8.2 kg [95% CI, 6.4-9.9], P = .02 for group × time interaction). Weight loss at 12 months, however, was similar in the 2 groups (12.1 kg [95% CI, 10.0-14.2] vs 9.9 kg [95% CI, 8.0-11.7], P = .25 for group × time interaction). Waist circumference, visceral abdominal fat, hepatic fat content, blood pressure, and insulin resistance were all reduced in both groups. The addition of physical activity promoted greater reductions in waist circumference and hepatic fat content.

Conclusion Among patients with severe obesity, a lifestyle intervention involving diet combined with initial or delayed initiation of physical activity resulted in clinically significant weight loss and favorable changes in cardiometabolic risk factors.

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Note: For editorial comment see p 1835.

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conditions, notably diabetes,8 the long- 
term health effects are not fully un- 
derstood. Moreover, bariatric surgery is per- 
formed in only 1% of severely obese 
adults annually, making it an unlikely 
public health solution for the rapidly in-
creasing prevalence of severe obesity. 
With regard to nonsurgical treatment of 
persons with severe obesity, it is fre-
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With regard to nonsurgical treatment of 
non- surgical treatment of obesity.11-13As a result, practitioners lack 
evidence-based guidelines for treatment 
of the most severely obese persons, argu-
ably the subgroup most seriously affected 
in the ongoing obesity epidemic.

We conducted a 1-year randomized 
trial to examine the effects of an inten-
sive lifestyle intervention on weight loss 
in severely obese adults. We specifically 
examined whether adoption of a physi-
cal activity program in addition to a di-
etary intervention would promote addi-
tional weight loss compared with a dietary 
intervention alone and whether these 
changes would differ in African Ameri-
can and white individuals. We also ex-
amined changes in waist circumference, 
visceral abdominal fat, hepatic steatosis, 
and other cardiometabolic risk factors.

**METHODS**

**Patient Recruitment**

Participants were recruited via televi-
sion and newspaper advertisements and 
mass mailings. The study was reviewed 
and approved by the human ethics com-
mittees of the University of Pittsburgh. 
Recruitment commenced in February 
2007, the last participant was random-
ized in March 2009, and all data were 
available for analysis in April 2010. All 
participants provided written informed 
consent to participate in the study.

**Inclusion/Exclusion Criteria**

Participants were eligible if they were be-
tween the ages of 30 and 55 years and 
had severe obesity, defined as body mass 
index between 35 and 39.9 (calculated as 
weight in kilograms divided by height 
in meters squared) for class II obesity 
and 40 or greater for class III obesity. Race/
ethnicity was self-reported. Partici-
pants had to be able to walk without 
assistance, commit to the schedule of in-
tervention and assessment visits, and ob-
tain medical clearance for intervention. 
Candidates were excluded if they had a 
history of cancer within the past 5 years, 
had a history of or were receiving cur-
tent treatment for coronary artery dis-
 ease, had enrolled within the past year 
in a formal weight reduction program, 
reported losing more than 5% of cur-
rent body weight in the previous 6 
months, had a history of bariatric sur-
gery, or had uncontrolled hyperten-
sion, diabetes, or pregnancy during the 
previous 6 months.

**Randomization**

Participants were randomized into 2 
study groups, with blocking according 
to sex, level of obesity (class II and III), 
and race/ethnicity (African American and 
white). Intervention assignment was 
blocked by race/ethnicity to ensure equal 
racial/ethnic representation across study 
groups. The study was single-blind; as-
sessors for all outcomes were blinded to 
participant group assignment, and all 
outcomes data were kept blinded until 
final data entry for 12-month assess-
ments was completed.

**Treatment Groups**

Participants were randomized to a 1-year 
lifestyle intervention consisting of diet 
and physical activity. One group was random-
ized to diet and physical activity for the 
entire 12 months (initial physical activ-
ity), while the other group had the iden-
tical dietary intervention but with physi-
ical activity delayed for 6 months (delayed 
physical activity). The behavioral lifestyle 
intervention program was delivered with 
a combination of group, individual, and 
telephone contacts.14 During months 1 
through 6, participants received 3 group 
meetings and 1 individual contact per 
month. During months 7 through 12, par-
ticipants received 2 group sessions and 2 
telephone contacts per month. All partici-
pants were prescribed a diet that we have 
shown to result in a sustained 8% to 10% 
weight loss in 12 months.15 Energy intake 
was reduced to 1200 to 2100 kcal/d based 
on initial body weight. Targeted macro-
nutrient composition was 20% to 30% fat, 
50% to 55% carbohydrate, and 20% to 
25% protein. To facilitate dietary compli-
ance and improve weight loss,16 liquid and 
prepackaged meal replacements were pro-
vided at no cost for all but 1 meal per day 
during months 1 through 3 and for only 
1 meal replacement per day during 
months 4 through 6 of the intervention. 
Adherence to the dietary intervention was 
monitored by having participants record 
the time of meals as well as the type and 
caloric value of food consumed.

A progressive physical activity pro-
gram was prescribed at the outset of treat-
ment for participants in the initial-activity 
group and following the initial 6 months 
of the dietary intervention for those in 
the delayed-activity group. Moderate-
intensity physical activity, similar in in-
tensity to brisk walking, was prescribed 
and progressed to 60 minutes, 5 days 
per week.16,17 To maximize adoption and 
maintenance of physical activity, partici-
pants were allowed to accumulate mul-
tiple 10-minute physical activity sessions 
per day, were provided with a pedom-
eter and step goals of more than 10 000 
steps per day, and were instructed to self-
monitor their physical activity in a 
weekly diary. Participants received mod-
est financial compensation for their par-
ticipation to offset costs incurred for their 
participation in the study. To promote 
adherence to the behavior intervention, 
participants were provided with low-cost 
supplies related to the intervention (eg, 
pedometer, exercise videos) and were 
eligible to periodically receive small fi-
nancial incentives for adherence to the 
behavioral goals of the intervention.

**Primary and Secondary Outcomes**

Body weight, height, and waist circum-
ference were measured using standard 
protocols.18 Body fat and fat-free mass 

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were determined either by dual-energy x-ray absorptiometry or by air-displacement plethysmography in 24 participants exceeding the weight capacity of the scanner (>136 kg). Computed tomography scans were performed at baseline and at 6 months to quantify abdominal adipose tissue and hepatic fat content as previously described. Other secondary outcomes included blood pressure and levels of fasting glucose, insulin, hepatic enzymes, and lipids including cholesterol and triglycerides. Insulin resistance was calculated using the homeostatic model assessment method. Multisensor physical activity monitors (Sensewear Pro3; BodyMedia, Pittsburgh, Pennsylvania) were worn between 7 and 11 consecutive days (mean, 7.2 [SD, 1.8] days; 23.1 [SD, 0.6] hours/d) at baseline, 6 months, and 12 months to provide objective measures of physical activity.

**Statistical Analysis**

Categorical variables were analyzed with χ² tests. Intention-to-treat analysis of primary and secondary outcomes was performed using SAS version 9.2 (SAS Institute Inc, Cary, North Carolina), with the type I error rate fixed at .05 (2-tailed). The Markov chain Monte Carlo method was used to impute missing data. A total of 10 imputations were generated. Separate mixed-effects models were fit for each of these outcomes, which were measured repeatedly at baseline, 6 months, and 12 months. Main effects of treatment group and time, as well as the treatment group × time interaction effect were examined in the mixed-effect models using the unstructured dependence structure. Least-square means were obtained from the mixed-effects models. Results from each imputation were then combined using the PROC MIANALYZE procedure in SAS.

Based on our results from a similar weight loss intervention study, an a priori power analysis was performed to determine the sample size necessary to detect significant weight loss in both groups combined at 12 months and difference at 6 months between the initial physical activity and delayed physical activity groups. Furthermore, a systematic review of the literature suggests that diet alone results in 2% to 3% less weight loss than what is achieved with the combination of diet plus physical activity. Therefore, assuming 6.5% weight loss in the initial-activity group and 9.0% in the delayed-activity group with an SD of 4.5% (effect size, 0.55) and with a fixed at .05 for a 2-tailed test and power set at 0.80, a sample size of 53 participants per experimental condition would be required to detect this difference in weight loss at 6 months. Assuming an attrition rate of 20%, this would require 64 participants per experimental condition (128 total participants). Thus, we randomized 130 participants in this study to provide a sufficient sample to detect these estimated differences in weight loss at 6 months.

**Figure 1. Flow of Participant Recruitment, Screening, and Assessment**

- 595 Individuals prescreened by telephone
  - 190 Excluded after a brief explanation of study and initial assessment of eligibility
  - 205 Invited to attend information sessions
  - 178 Excluded
    - 164 Did not attend
    - 14 Not interested
  - 227 Underwent clinical assessment
    - 97 Excluded
      - 25 Withdrew
      - 19 Liver enzymes >30% above normal
      - 12 Adherence issues
      - 11 Hematocrit <34%
      - 9 Fasting glucose >125 mg/dL
      - 7 Medication exclusion
      - 6 Uncontrolled hypertension
      - 3 Thyrotropin >8 mIU/L
      - 2 Health issues
      - 1 Proteinuria
      - 1 Cancer
      - 1 No medical clearance
  - 130 Randomized
    - 67 Randomized to diet and initial physical activity
      - 67 Underwent intervention as randomized
        - 6-Month follow-up
          - 61 Completed assessment visit
            - 6 Lost to follow-up
            - 5 Could not be reached
            - 1 Withdrew
        - 12-Month follow-up
          - 49 Completed assessment visit
            - 12 Lost to follow-up (could not be reached)
            - 6 Included in primary analysis
      - 63 Underwent intervention as randomized
        - 6-Month follow-up
          - 57 Completed assessment visit
            - 6 Lost to follow-up (could not be reached)
        - 12-Month follow-up
          - 52 Completed assessment visit
            - 5 Lost to follow-up
            - 4 Could not be reached
            - 1 Withdrew
          - 63 Included in primary analysis

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### RESULTS

#### Study Participants

The flow of study participants is shown in Figure 1. Retention rates for the initial physical activity group were 90% at 6 months and 73% at 12 months. Retention rates for the delayed physical activity group were 90% at 6 months and 83% at 12 months. These rates were not different between groups. The baseline characteristics of the study groups are shown in Table 1. There were no significant differences in demographics or characteristics contributing to outcomes between study groups among those enrolled in the study. Seventy-five percent of participants had class III obesity, and

#### Table 1. Baseline Characteristics of Initial Physical Activity and Delayed Physical Activity Groups

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial Activity (n = 67)</th>
<th>Delayed Activity (n = 63)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>46.1 (6.5)</td>
<td>47.5 (6.2)</td>
<td>.19</td>
</tr>
<tr>
<td>Men</td>
<td>10 (14.9)</td>
<td>5 (7.9)</td>
<td>.21</td>
</tr>
<tr>
<td>African American</td>
<td>25 (37.3)</td>
<td>23 (36.5)</td>
<td>.92</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>43.5 (4.8)</td>
<td>43.7 (6.9)</td>
<td>.85</td>
</tr>
<tr>
<td>Obesity severitya</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class II</td>
<td>17 (25)</td>
<td>15 (24)</td>
<td>.84</td>
</tr>
<tr>
<td>Class III</td>
<td>50 (75)</td>
<td>48 (76)</td>
<td>.84</td>
</tr>
<tr>
<td>Blood pressure medication</td>
<td>22 (32.8)</td>
<td>23 (36.5)</td>
<td>.99</td>
</tr>
<tr>
<td>Lipid-lowering medication</td>
<td>4 (6.0)</td>
<td>6 (9.5)</td>
<td>.99</td>
</tr>
<tr>
<td>Smoker</td>
<td>8 (11.9)</td>
<td>3 (4.8)</td>
<td>.99</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; CI, confidence interval. a Calculated as weight in kilograms divided by height in meters squared. b Class II defined as BMI between 35 and 39.9; class III defined as BMI of 40 or greater.

#### Table 2. Change in Body Weight, Body Composition, and Metabolic Parameters

<table>
<thead>
<tr>
<th>Outcome Variable</th>
<th>Baseline (n = 67)</th>
<th>Month 6 (n = 62)</th>
<th>Month 12 (n = 57)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight, kg</td>
<td>120.58 (116.34-124.81)</td>
<td>109.68 (105.66-113.69)</td>
<td>108.46 (103.95-112.96)</td>
<td>&lt;.0001 &lt;.0001 .30 .02 .25</td>
</tr>
<tr>
<td>BMI</td>
<td>117.37 (113.00-121.73)</td>
<td>109.21 (105.11-113.31)</td>
<td>107.50 (102.99-112.01)</td>
<td>&lt;.0001 &lt;.0001 .86 .06 .40</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>124.35 (121.42-127.28)</td>
<td>115.75 (112.76-118.75)</td>
<td>114.15 (110.73-117.57)</td>
<td>&lt;.0001 &lt;.0001 .22 .01 .27</td>
</tr>
<tr>
<td>Abdominal subcutaneous fat, cm²</td>
<td>718.00 (675.26-760.80)</td>
<td>605.21 (566.69-643.74)</td>
<td>NAb</td>
<td>.003 NA .99 .16 NA</td>
</tr>
<tr>
<td>Visceral fat, cm²</td>
<td>199.39 (180.46-218.33)</td>
<td>170.66 (155.77-185.55)</td>
<td>NAb</td>
<td>.004 NA .47 .046 NA</td>
</tr>
<tr>
<td>Liver fat, liver-spleen HU</td>
<td>1.06 (1.00-1.12)</td>
<td>1.18 (1.14-1.22)</td>
<td>NAb</td>
<td>.004 NA .47 .046 NA</td>
</tr>
<tr>
<td>Body fat, kg</td>
<td>60.40 (57.40-63.40)</td>
<td>51.74 (48.89-54.59)</td>
<td>51.23 (47.99-54.47)</td>
<td>&lt;.0001 &lt;.0001 .60 .008 .27</td>
</tr>
<tr>
<td>Fat-free mass, kg</td>
<td>59.24 (56.08-62.39)</td>
<td>53.33 (50.34-56.33)</td>
<td>51.90 (48.55-55.26)</td>
<td>&lt;.0001 &lt;.0001 .18 .52 .49</td>
</tr>
<tr>
<td>Systolic BP, mm Hg</td>
<td>135.43 (132.08-138.78)</td>
<td>132.04 (128.14-135.94)</td>
<td>120.60 (116.22-124.98)</td>
<td>.37 &lt;.001 .68 .80 &gt;.99</td>
</tr>
<tr>
<td>Diastolic BP, mm Hg</td>
<td>78.01 (75.97-80.05)</td>
<td>75.68 (73.29-78.08)</td>
<td>72.38 (70.31-74.46)</td>
<td>.25 &lt;.001 .50 .67 .82</td>
</tr>
<tr>
<td>Mean arterial pressure, mm Hg</td>
<td>96.96 (94.61-99.31)</td>
<td>94.12 (91.36-96.87)</td>
<td>88.36 (85.68-91.04)</td>
<td>.30 &lt;.001 .55 .51 .98</td>
</tr>
</tbody>
</table>

(continued)
these proportions were similar in the study groups (Table 1). There were no racial/ethnic differences in body weight or body fat at baseline. Participants who dropped out were similar to those who completed intervention, except they were younger (44.1 years [SD, 6.9] vs 47.5 years [SD, 6.0], P = .02).

**Weight Loss**
The initial physical activity group received 75.1% (SD, 27.3%) of total intended intervention contact, which was not different compared with 71.9% (SD, 25.6%) for the delayed physical activity group (P = .49). Both groups lost a significant amount of weight at 6 months (10.9 kg [95% confidence interval (CI), 9.1-12.7] vs 8.2 kg [95% CI, 6.4-9.9]) and 12 months (12.1 kg [95% CI, 10.0-14.2] vs 9.9 kg [95% CI, 8.0-11.7]) (Table 2, Figure 2). The initial-activity group lost significantly more weight in the first 6 months compared with the delayed-activity group. While the magnitude of weight loss did not differ between groups at 12 months, the significant group × time interaction (P = .02) reflects the greater weight loss at 6 months in the initial-activity compared with the delayed-activity group (Table 2).

In a secondary analysis of study completers (Figure 3), 80% of initial-activity participants vs 60% of delayed-activity participants lost more than 5% of their baseline body weight at 6 months, whereas the percentage of participants achieving this magnitude of weight loss at 12 months was 78% in the initial-activity group vs 65% in the delayed-activity group. The heavier class II obese participants in our study lost significantly more weight than class II obese participants (10.9% [95% CI, 8.9%-13.0%] vs 7% [95% CI, 4.2%-9.9%]) at 12 months; (P = .047), although the intervention group did not confound these differences. The pattern of results comparing the intervention groups, however, was not affected when either obesity class or race/ethnicity was included in the analysis. Moreover, the intervention effects were consistent when outcomes were analyzed using

### Table 2. Change in Body Weight, Body Composition, and Metabolic Parameters (continued)

<table>
<thead>
<tr>
<th>Outcome Variable</th>
<th>Baseline</th>
<th>Month 6</th>
<th>Month 12</th>
<th>P Value</th>
<th>Time</th>
<th>Group</th>
<th>Group × Time Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline phosphatase, U/L</td>
<td>Initial activity (n = 67)</td>
<td>86.46 (81.95-90.98)</td>
<td>77.29 (72.71-81.88)</td>
<td>70.20 (65.74-74.66)</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td>Delayed activity (n = 63)</td>
<td>86.30 (81.64-90.96)</td>
<td>78.54 (73.63-83.45)</td>
<td>72.98 (68.40-77.56)</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.96</td>
</tr>
<tr>
<td>ALT, U/L</td>
<td>Initial activity (n = 67)</td>
<td>30.58 (28.42-32.74)</td>
<td>28.79 (26.49-31.09)</td>
<td>22.09 (19.96-24.23)</td>
<td>.02</td>
<td>&lt;.001</td>
<td>.86</td>
</tr>
<tr>
<td></td>
<td>Delayed activity (n = 63)</td>
<td>30.30 (28.07-32.53)</td>
<td>27.83 (25.49-30.17)</td>
<td>23.53 (21.34-25.31)</td>
<td>.049</td>
<td>.32</td>
<td>.41</td>
</tr>
<tr>
<td>AST, U/L</td>
<td>Initial activity (n = 67)</td>
<td>25.81 (24.26-27.35)</td>
<td>23.82 (22.09-25.55)</td>
<td>23.71 (21.58-25.86)</td>
<td>&lt;.001</td>
<td>.12</td>
<td>.45</td>
</tr>
<tr>
<td></td>
<td>Delayed activity (n = 63)</td>
<td>24.87 (23.28-26.46)</td>
<td>23.28 (21.53-25.03)</td>
<td>23.77 (21.96-25.65)</td>
<td>&lt;.001</td>
<td>.12</td>
<td>.45</td>
</tr>
<tr>
<td>Total cholesterol, mg/dL</td>
<td>Initial activity (n = 67)</td>
<td>185.75 (178.05-193.44)</td>
<td>181.64 (173.89-194.40)</td>
<td>184.55 (175.88-193.22)</td>
<td>.72</td>
<td>.81</td>
<td>.20</td>
</tr>
<tr>
<td></td>
<td>Delayed activity (n = 63)</td>
<td>192.94 (185.00-200.87)</td>
<td>191.92 (183.90-199.96)</td>
<td>192.09 (183.17-201.00)</td>
<td>.001</td>
<td>.78</td>
<td>.80</td>
</tr>
<tr>
<td>HDL-C, mg/dL</td>
<td>Initial activity (n = 67)</td>
<td>47.27 (44.63-49.90)</td>
<td>44.89 (42.20-47.59)</td>
<td>45.88 (42.86-48.90)</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.46</td>
</tr>
<tr>
<td></td>
<td>Delayed activity (n = 63)</td>
<td>48.71 (46.00-51.43)</td>
<td>45.10 (42.47-47.96)</td>
<td>47.07 (44.08-50.03)</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.46</td>
</tr>
<tr>
<td>Triglycerides, mg/dL</td>
<td>Initial activity (n = 67)</td>
<td>127.51 (112.23-142.79)</td>
<td>123.23 (109.35-137.11)</td>
<td>115.53 (100.52-130.54)</td>
<td>.27</td>
<td>.20</td>
<td>.77</td>
</tr>
<tr>
<td></td>
<td>Delayed activity (n = 63)</td>
<td>124.29 (108.53-140.04)</td>
<td>131.90 (116.71-147.08)</td>
<td>114.54 (98.82-130.27)</td>
<td>.07</td>
<td>.78</td>
<td>.80</td>
</tr>
<tr>
<td>Glucose, mg/dL</td>
<td>Initial activity (n = 67)</td>
<td>93.69 (80.94-96.43)</td>
<td>90.11 (87.49-92.73)</td>
<td>92.51 (89.57-96.46)</td>
<td>.07</td>
<td>.78</td>
<td>.80</td>
</tr>
<tr>
<td></td>
<td>Delayed activity (n = 63)</td>
<td>93.17 (80.35-96.00)</td>
<td>90.66 (87.85-93.47)</td>
<td>93.65 (90.66-96.65)</td>
<td>.049</td>
<td>.46</td>
<td>.63</td>
</tr>
<tr>
<td>Insulin, µU/mL</td>
<td>Initial activity (n = 67)</td>
<td>17.07 (14.81-19.33)</td>
<td>12.06 (10.36-13.75)</td>
<td>12.33 (10.21-14.46)</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.46</td>
</tr>
<tr>
<td></td>
<td>Delayed activity (n = 63)</td>
<td>15.83 (13.37-18.30)</td>
<td>11.61 (9.86-13.36)</td>
<td>11.55 (9.22-13.88)</td>
<td>&lt;.001</td>
<td>.01</td>
<td>.40</td>
</tr>
<tr>
<td>HOMA-IR</td>
<td>Initial activity (n = 67)</td>
<td>4.03 (3.47-4.60)</td>
<td>2.70 (2.30-3.11)</td>
<td>2.87 (2.35-3.38)</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.40</td>
</tr>
<tr>
<td></td>
<td>Delayed activity (n = 63)</td>
<td>3.68 (3.07-4.28)</td>
<td>2.65 (2.13-3.29)</td>
<td>2.73 (2.16-3.29)</td>
<td>&lt;.001</td>
<td>.01</td>
<td>.40</td>
</tr>
</tbody>
</table>

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; BP, blood pressure; CI, confidence interval; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, homeostasis model assessment of insulin resistance; HU, Hounsfield units; NA, not available.

SI conversion factors: To convert total cholesterol and HDL-C values from mg/dL to mmol/L, multiply by 0.0259; triglyceride values from mg/dL to mmol/L, by 0.0113; glucose values from mg/dL to mmol/L, by 0.0555; and insulin values from µIU/mL to pmol/L, by 6.945.

*aMeans with multiple imputation used for missing data.

*bNumber of liver-fat measurements at baseline in the initial-activity group is 66, because 1 organ scan was of poor quality.

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baseline observations carried forward (eTable, available at http://www.jama.com) or with mixed-effects modeling using data missing at random.

**Body Composition, Waist Circumference, Visceral Adiposity, and Hepatic Fat**

Both groups had a significant reduction in body fat and waist circumference at 6 and 12 months (Table 2). The initial physical activity group, however, had significantly greater reductions in body fat and waist circumference at 6 months compared with the delayed physical activity group. However, there were no differences in body fat or waist circumference at the completion of the subsequent 6 months, at which time both groups were engaged in physical activity. Both groups lost a significant but similar amount of visceral abdominal and subcutaneous abdominal adipose tissue in the first 6 months. Hepatic fat content was also decreased in both groups, although this decrease was significantly greater in the initial-activity group.

**Physical Activity**

The study groups engaged in similar amounts of physical activity at baseline as measured by the number of steps per day and the amount of time engaged in vigorous activity, the latter defined by minutes per week spent in activity with more than 6 metabolic equivalent tasks. At 6 months, the initial-activity group had significantly (P < .001) increased the number of steps per day from 7048 (SD, 2886) to 8475 (SD, 2927) and was engaged in approximately twice the amount of vigorous physical activity (71 [SD, 88 min/wk vs 34 [SD, 49] min/wk, respectively; P = .01). The delayed-activity group did not significantly increase their physical activity in the first 6 months. The initial-activity group maintained their amount of physical activity between 6 and 12 months, while the delayed-activity group significantly increased the number of daily steps (7047 [SD, 2597] steps to 7991 [SD, 2949] steps, P = .01) and minutes of vigorous activity (36 [SD, 49] to 53 [SD, 70], P = .03) completed per week from baseline to 12 months, at which time there was no difference in the amount of physical activity between the groups.

**Other Health Outcomes**

Table 2 shows changes in selected clinical measures of health, mostly related to cardiometabolic risk factors. Blood pressure was significantly and similarly reduced in both intervention groups. Levels of serum liver enzymes were reduced in both groups. Fasting insulin and insulin resistance improved significantly and similarly in both intervention groups. There was no difference in adverse events between groups. There was no significant measurable change in use of antihypertensive or lipid-lowering medications, nor was there a between-group difference in medication use.

**COMMENT**

This study is to our knowledge the first designed specifically to examine the effects of an intensive lifestyle intervention on weight loss, abdominal fat, hepatic steatosis, and other cardiometabolic risk factors in persons with severe obesity. Our results indicate that this non-
Our study likely contributed to the retention rates of participants lost 10% or more of their weight at 12 months. Adherence to the intervention by these severely obese participants was the same as that previously reported in overweight and obese participants. This is in accord with the findings of a study that reported significant weight loss in severe obesity. Our results directly counter the dogma that these severely obese individuals do not respond to lifestyle intervention. In addition, despite the slightly lower weight loss in African Americans, the interventions were effective in white as well as African American individuals, the latter of whom are at particular risk for type 2 diabetes and cardiovascular disease.

Our results are consistent with studies in overweight and class I obese participants reporting that the addition of physical activity modestly but significantly induces greater weight loss and is important to maintain weight loss. Moreover, these severely obese adults did not present with any particular physical limitations that precluded them from initiating a physical activity program at the onset of the weight loss intervention. This suggests that physical activity could also play an important role in the long-term maintenance of weight loss following bariatric surgery, which is in accord with previous associations between physical activity and degree of weight loss following bariatric surgery. Additional studies are clearly needed, however, to examine the long-term effects of physical activity on weight loss in severe obesity.

Another clinically relevant finding was the significant reduction in abdominal fat and hepatic steatosis. Abdominal fat assessed by imaging methods or by surrogate waist circumference is regarded as more strongly associated with type 2 diabetes and cardiovascular disease risk than is generalized obesity. Moreover, a large prospective cohort analysis revealed that higher waist circumference strongly predicts mortality. Hepatic steatosis is strongly associated with insulin resistance and a higher risk of cardiovascular disease. Although this lifestyle intervention did not achieve the degree of weight loss typically observed following bariatric surgery, this magnitude of weight loss was associated with significant improvements in insulin resistance, blood pressure, and levels of plasma triglycerides. Moreover, the greater reductions in waist circumference and degree of hepatic steatosis with the addition of physical activity indicate that the benefits of physical activity extend beyond effects on generalized obesity.

Our study also has several limitations. Participants were mostly women, and although groups were randomized according to sex, it is difficult to determine sex-specific responses. Additional studies should examine the effects of sustained intensive lifestyle intervention on long-term weight loss among severely obese persons and on the use of antihypertensive and lipid-lowering medications.

In conclusion, intensive lifestyle interventions using a behavior-based approach can result in clinically significant and meaningful weight loss and improvements in cardiometabolic risk factors in severely obese persons. It is also clear that physical activity should be incorporated early in any dietary restriction approach to induce weight loss and to reduce hepatic steatosis and abdominal fat. Our data make a strong case that serious consideration should be given by health care systems to incorporating more intensive lifestyle interventions similar to those used in our study. Additional studies are clearly needed to determine long-term efficacy and cost-effectiveness of such approaches.

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Author Contributions: Dr Goodpaster had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Diet and Physical Activity in Severely Obese Adults

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Online-Only Material: The eTable is available at http://www.jama.com.

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