# Effects of the Amount of Exercise on Body Weight, Body Composition, and Measures of Central Obesity

## *STRRIDE—A Randomized Controlled Study*

*Cris A. Slentz, PhD; Brian D. Duscha, MS; Johanna L. Johnson, MS; Kevin Ketchum, MS; Lori B. Aiken, BS; Gregory P. Samsa, PhD; Joseph A. Houmard, PhD; Connie W. Bales, PhD, RD; William E. Kraus, MD*

**Background:** Obesity is a major health problem due, in part, to physical inactivity. The amount of activity needed to prevent weight gain is unknown.

**Objective:** To determine the effects of different amounts and intensities of exercise training.

**Design:** Randomized controlled trial (February 1999–July 2002).

**Setting and Participants:** Sedentary, overweight men and women (aged 40-65 years) with mild to moderate dyslipidemia were recruited from Durham, NC, and surrounding communities.

**Interventions:** Eight-month exercise program with 3 groups: (1) high amount/vigorous intensity (calorically equivalent to approximately 20 miles [32.0 km] of jogging per week at 65%-80% peak oxygen consumption); (2) low amount/vigorous intensity (equivalent to approximately 12 miles [19.2 km] of jogging per week at 65%-80%), and (3) low amount/moderate intensity (equivalent to approximately 12 miles [19.2 km] of walking per week at 40%-55%). Subjects were counseled not to change their diet and were encouraged to maintain body weight.

**Main Outcome Measures:** Body weight, body composition (via skinfolds), and waist circumference.

**Results:** Of 302 subjects screened, 182 met criteria and were randomized and 120 completed the study. There was a significant ($P<.05$) dose-response relationship between amount of exercise and amount of weight loss and fat mass loss. The high-amount/vigorous-intensity group lost significantly more body mass (in mean [SD] kilograms) and fat mass (in mean [SD] kilograms) (–2.9 [2.8] and –4.8 [3.0], respectively) than the low-amount/moderate-intensity group (–0.9 [1.8] and –2.0 [2.6], respectively), the low-amount/vigorous-intensity group (–0.6 [2.0] and –2.5 [3.4], respectively), and the controls (+1.0 [2.1] and +0.4 [3.0], respectively). Both low-amount groups had significantly greater improvements than controls but were not different from each other. Compared with controls, all exercise groups significantly decreased abdominal, minimal waist, and hip circumference measurements. There were no significant changes in dietary intake for any group.

**Conclusions:** In nondieting, overweight subjects, the controls gained weight, both low-amount exercise groups lost weight and fat, and the high-amount group lost more of each in a dose-response manner. These findings strongly suggest that, absent changes in diet, a higher amount of activity is necessary for weight maintenance and that the positive caloric imbalance observed in the overweight controls is small and can be reversed by a modest amount of exercise. Most individuals can accomplish this by walking 30 minutes every day.

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*Author affiliations are listed at the end of this article. The authors have no relevant financial interest in this article.*

OVERWEIGHT OR OBESITY IS seen in 55% of Americans.[1] From 1991 to 1998, obesity prevalence increased by almost 50%.[2] Overweight and obese individuals are at increased risk for cardiovascular diseases, diabetes, hypertension, and other health disorders.[3] However, centrally located excess weight is even more clearly associated with health risk,[4,5] and as a result, recent clinical guidelines[3] have indicated that disease risk is best categorized by both body mass index (BMI) and waist circumference.

Most would agree that, in addition to diet, decreases in leisure and work-related physical activity play an important role[6-8] in the rapid increases in obesity prevalence over the last few decades. However, the amount of activity to prevent weight gain is not known. In 1995, the Centers for Disease Control and Prevention and the American College of Sports Medicine jointly issued a health statement recommending that "Every US adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week."[9] However, the Institute of Medi-



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cine of the National Academies recently stated that "30 minutes per day of regular activity is insufficient to maintain body weight in adults. . . ."[10] Instead, they recommend 60 minutes of moderate-intensity physical activity per day to prevent weight gain. Clearly this is a controversial area, and the medical community is left not knowing what amount of exercise to recommend for weight loss, weight maintenance, and general health promotion. Interestingly, to our knowledge there are no prospective exercise training studies that compare the effects of 2 or more different amounts of physical activity on changes in body weight, body composition, or measures of central obesity.

Studies of Targeted Risk Reduction Interventions through Defined Exercise (STRRIDE), a randomized controlled clinical trial, was designed to investigate the separate and combined effects of the amount of exercise and exercise intensity on cardiovascular risk factors in overweight and mildly obese men and women with mild to moderate dyslipidemia. In the present article we report data suggesting that even in the absence of reduced calorie intake, most overweight and mildly obese individuals can accumulate enough physical activity to prevent weight gain and even promote modest weight loss by performing moderate-intensity exercise for 30 min/d. More activity resulted in greater weight loss, fat loss, and reductions in measures of central obesity.

## METHODS

### SUBJECTS

A complete description of the STRRIDE design, hypotheses, recruitment strategies, methods, and preliminary results are published elsewhere.[11] Informed consents were signed by 302 subjects from Durham, NC, and surrounding communities, who were assessed for eligibility. Of these 302 subjects, 182 met inclusion criteria and were randomized into the study. The study was completed by 120 subjects (66% of those randomized), who were included in this analysis. Inclusion criteria were age 40 to 65 years, sedentary (exercised less than once weekly), overweight or mildly obese (BMI [calculated as weight in kilograms divided by the square of height in meters], 25-35) with mild to moderate lipid abnormalities (either low-density lipoprotein cholesterol [LDL-C] = 130-190 mg/dL [3.4-4.9 mmol/L] or high-density lipoprotein cholesterol [HDL-C] <40 mg/dL [<1.0 mmol/L] for men or <45 mg/dL [<1.2 mmol/L] for women), nondiabetic, and nonhypertensive. Women were also postmenopausal. Exclusion criteria included other metabolic or musculoskeletal diseases, currently dieting or intent to diet; use of confounding medications, overt presence of coronary heart disease, and unwillingness to be randomized to any group. After written informed consent was obtained, subjects were randomly assigned to 1 of 3 exercise training groups or to a nonexercising control group.

### EXERCISE TRAINING PROTOCOLS

The exercise groups were as follows: (1) high amount/vigorous intensity (caloric equivalent to approximately 20 miles [32.0 km]/wk at 65%-80% peak oxygen consumption [$\dot{V}O_2$]), (2) low amount/vigorous intensity (caloric equivalent to approximately 12 miles [19.2 km]/wk at 65%-80% peak $\dot{V}O_2$), and (3) low amount/moderate intensity (caloric equivalent of approximately 12 miles [19.2 km]/wk at 40%-55% peak $\dot{V}O_2$). For the high-amount/vigorous-intensity group, the specific exercise prescription was to expend 23 kcal/kg of body weight per week, which is the caloric equivalent of approximately 20 miles (32.0 km)/wk of walking or jogging for a 90-kg person (range, 19.2-20.6 miles [30.7-33.0 km]/wk for a 70-110–kg person).[12] The exercise prescription was 14 kcal/kg per week for the 2 low-amount groups, which is the caloric equivalent of approximately 12 miles (19.2 km)/wk.[12] While the amount of exercise is expressed in terms of walking or jogging, the actual exercise modes included cycle ergometers, treadmills, and elliptical trainers.

### EXERCISE TRAINING

All exercise sessions were verified by direct supervision or use of a heart rate monitor that provides recorded data (Polar Electro Inc, Woodbury, NY). Compliance was calculated as a percentage and was equal to the actual number of exercise minutes completed each week at the appropriate intensity, divided by the total number of prescribed minutes:

$$(\text{Completed Exercise Minutes/Prescribed Minutes}) \times 100 = \text{Percentage}.$$

Data from all subjects who completed the study were used in the present study following an intent-to-treat design. There was an initial ramp period of 2 to 3 months in which exercise duration (in minutes) and exercise intensity were gradually increased until the appropriate exercise prescription was obtained. The initial ramp was followed by 6 additional months of training at the appropriate exercise prescription.

### DIETARY EVALUATIONS AND CONTROL OF BODY WEIGHT

Nutrient intakes of each subject were determined before and after exercise training using a 3-day food record and a 24-hour dietary recall interview. To study the effects of exercise alone and to eliminate the confounding effects of major weight loss, subjects were counseled to maintain baseline body weight. Subjects were recruited with the knowledge that this was an exercise study, not a weight loss study and as such, if their intent was to lose weight they should not participate. This was emphasized during the phone screening, during the initial consent meeting, and at the baseline dietary interview. Before written consent was obtained, subjects were informed that if they lost or gained 2.5% or more of their body weight, a nutrition counselor would collect and analyze their recent nutrient intake and suggest methods to maintain or increase their body weight. Specifically, if the nutritional information suggested that they had decreased their caloric intake or that their percentage of calories from a specific macronutrient (eg, fat, carbohydrate, or protein) had changed, they were advised to go back to their baseline eating habits. Given the relatively short duration of the intervention phase of this study (9 months), it was not believed that the instructions to maintain body weight would present a significant health risk to subjects.

### BODY WEIGHT, BODY COMPOSITION, SKINFOLDS, AND CIRCUMFERENCE MEASURES

Body height (to the nearest 0.64 cm) and weight was measured in light clothing and without shoes to the nearest tenth of a kilogram on a digital electronic scale (Scale 5005; Scale-Tronix Inc, Wheaton, Ill). To minimize day-to-day body weight variability, the average of 2 baseline and 2 end-of-study body weight measurements were used. Height was measured to the nearest fourth of an inch. Body composition was determined using the sum of 4 skinfolds measured with Lange calipers (Beta Technology Inc, Cambridge, Md) and the sex-specific formulas of Jackson and Pollock.[13] Skinfolds included triceps (vertical fold, midway between acromion, and olecranon pro-



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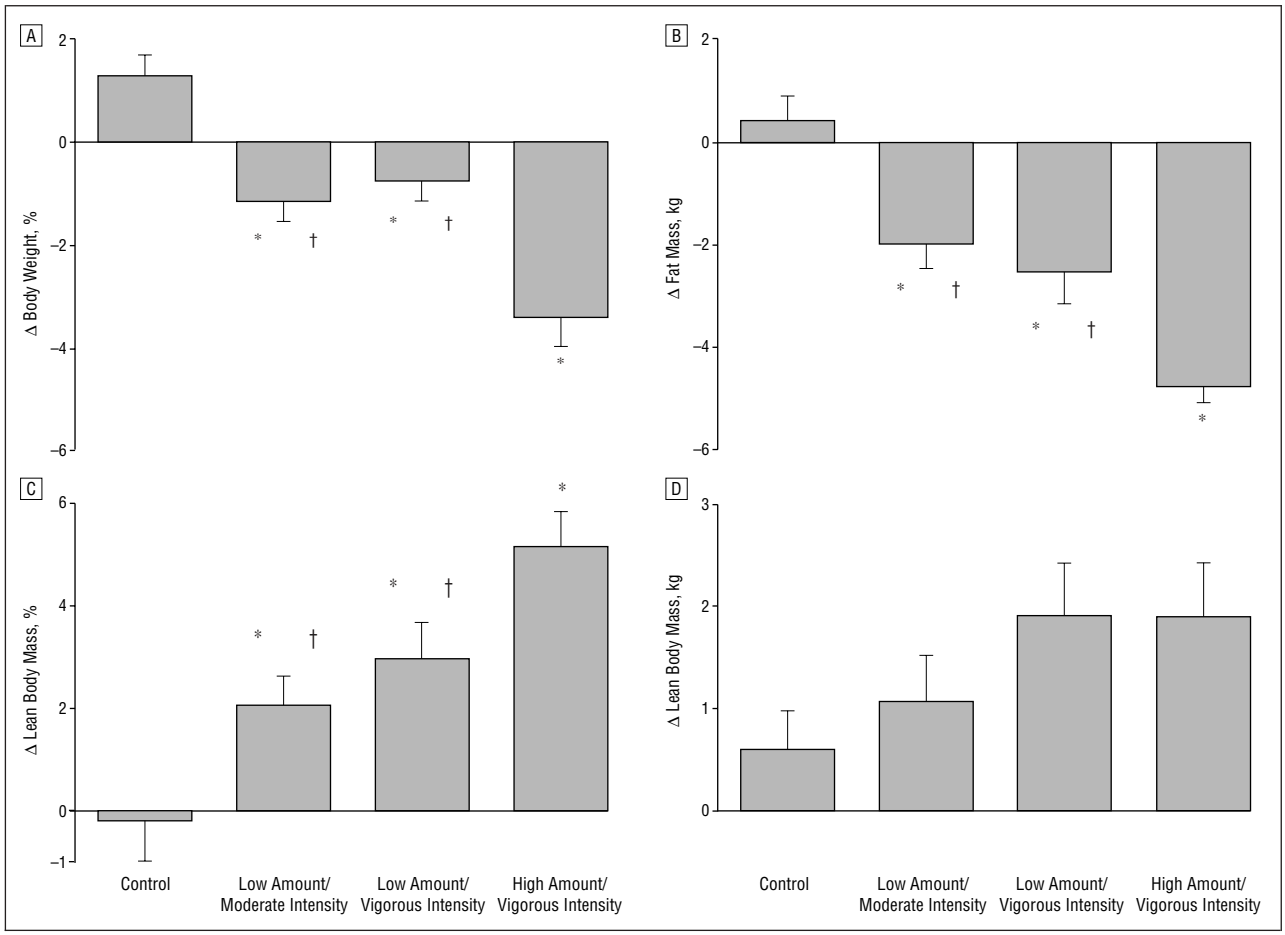


**Figure 1.** Effects of exercise amount and intensity on mean changes in body weight (A), fat mass (B), percent lean body mass (C), and lean body mass (D). The asterisk indicates $P<.05$ compared with controls; dagger, $P<.05$ compared with high-amount exercise group. Error bars show SE.

cesses on the posterior surface), suprailiac (diagonal fold above the iliac crest even with the anterior axillary line), abdominal (vertical fold approximately 1 in [2.54 cm] from umbilicus, right side), and thigh (vertical fold on anterior surface, midway between anterior, superior iliac process and the proximal border of the patella).[14] Circumferences were measured at the abdominal waist (horizontal at the umbilicus), minimal waist (smallest horizontal circumference above the umbilicus and below the xiphoid process), hips (horizontal, at maximal protrusion of gluteus maximus) and thigh (perpendicular to the femur at the midpoint between the hip and knee joints) as described in the American College of Sports Medicine Guidelines.[14]

### STATISTICAL METHODS

Data were analyzed using analysis of variance (Statview or SAS software; SAS Institute, Cary, NC). When the analysis of variance was significant ($P<.05$), a Student-Newman-Keuls post hoc analysis, which controlled for multiple comparisons, was performed to determine differences between groups (**Figures 1**, **2**, and **3**). Six pairwise comparisons (all 3 exercise groups compared with each other and exercise groups compared with the control group) were of interest. A *P* value, corrected for multiple comparisons, of less than .05 was considered significant.

Many of the analyses by analysis of variance are on percent change instead of the actual change score. This was done so that large weight losses from heavier individuals did not carry more weight than smaller but equal percent changes from smaller individuals (same for skinfolds and circumferences). For example the weight loss for women was less than for men if presented as an actual change score but was nearly identical when presented on a percent change basis. However, the statistically significant results were almost identical whether performed on absolute change scores or percent change scores. Paired *t* tests were used to determine if the postscore vs prescore for each group was significant. Finally, to determine if central body fat distribution was preferentially improved by exercise, a paired *t* test comparing the percent change in the sum of the 2 central skinfolds (abdominal and suprailiac) with that of the 2 peripheral skinfolds (thigh and tricep) was performed. All *t* tests are 2-tailed.

## RESULTS

### DEMOGRAPHICS

**Table 1** describes the baseline characteristics of the total group and of each separate group after randomization. There were no significant differences between groups on any baseline characteristic. There were a nearly equal number of men and women in each group, and minorities made up an average of 20% of the total study population. In addition, no changes in caloric intake were observed in any group. **Figure 4** describes the number of subjects screened (n=302), with 120 subjects who were screened out and 182 who were randomized. Of the 182 subjects randomized, 120 completed the study and are described in this article. No subjects were excluded. The



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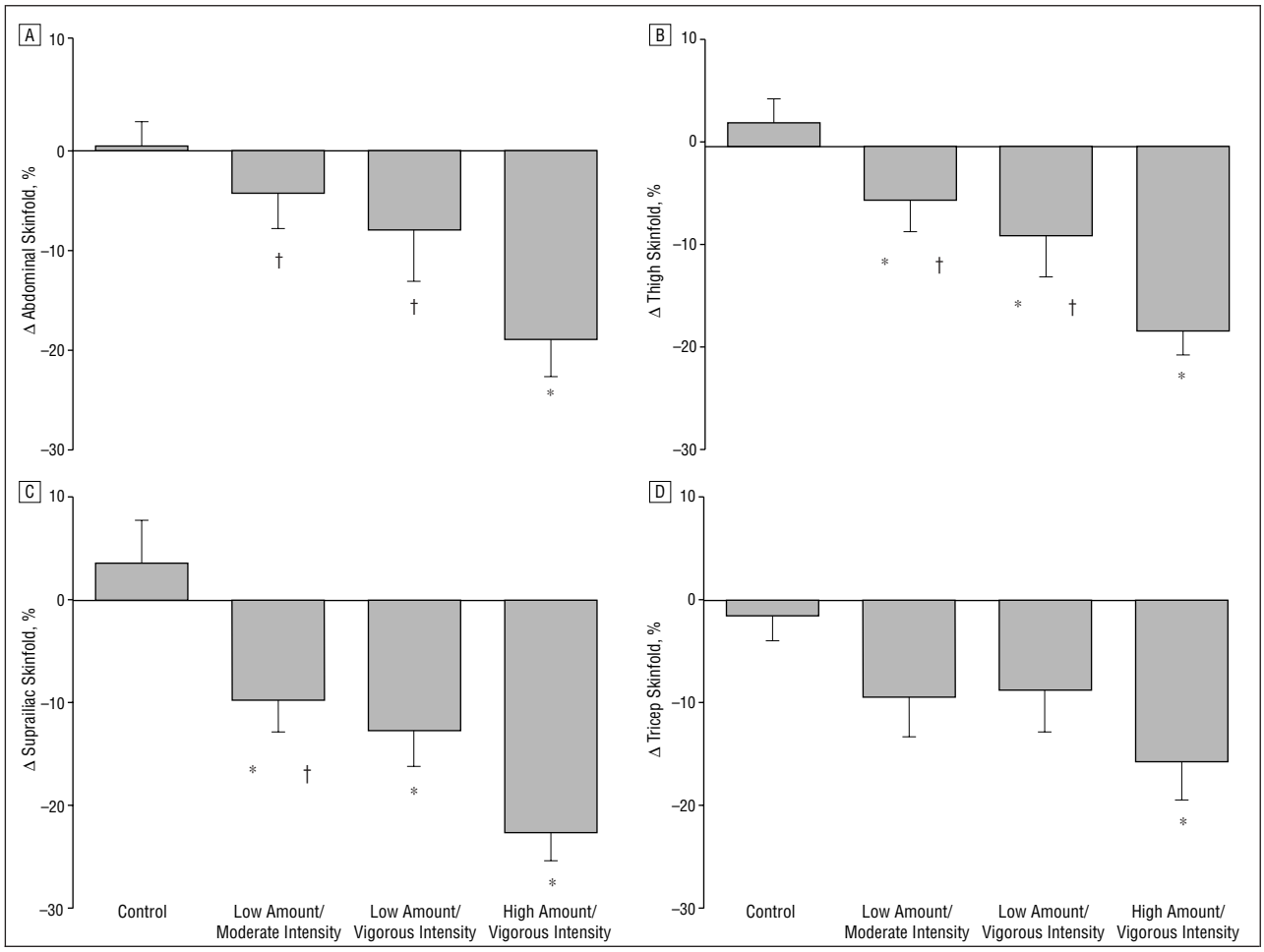


**Figure 2.** Effects of exercise amount and intensity on mean percent skinfold changes in abdominal (A), thigh (B), suprailiac (C), and tricep (D). The asterisk indicates $P<.05$ compared with controls; dagger, $P<.05$ compared with high-amount exercise group. Error bars show SE.

dropouts were not different from the those who completed the study on any baseline characteristic.

## EXERCISE PRESCRIPTION

Table 1 also describes the exercise prescription in detail. The specific amount of exercise prescribed (14 kcal/kg of body weight per week for both low-amount groups and 23 kcal/kg per week for the high-amount group), if converted (based on caloric expenditure equivalents) into number of miles per week, corresponds to approximately 12 and 20 miles (19.2 and 32.0 km) of walking or jogging for the low- and high-amount groups, respectively. Based on adherence, the low-amount groups averaged about 11 miles (17.6 km)/wk and the high-amount group averaged about 17 miles (27.2 km)/wk. The average number of minutes performed by each group is given in Table 1. The amount of time needed to expend the prescribed number of calories depends only on fitness levels, with the lower fit individuals requiring more time and higher fit individuals requiring less time to expend a given number of calories per kilogram of body mass. Of the 28 overweight/mildly obese participants in the low-amount/moderate-intensity exercise group (similar to a moderate to brisk walking pace), 24 (86%) completed this amount of exercise in 215 min/wk, which is equivalent to 31 min/d.

## BASELINE VALUES AND CHANGE SCORES

There were no significant changes in mean daily caloric intake or in carbohydrate, fat, or protein intake. In **Table 2**, the baseline values and the effects of exercise training on body mass, body composition, and anthropometric and fat distribution variables (change scores: postvalue – prevalue) are presented. The effect of exercise amount and intensity as well as the effect of no regular exercise on these variables are of a consistent, clear, dose-response nature. It is interesting that while exercise did not appear to preferentially decrease central body fat over peripheral fat, the effect of no regular exercise (ie, the controls) appeared to result in preferential increases in central body skinfolds more than peripheral skinfolds. The effect was small, however, and the difference was not significant. The waist-hip ratio at baseline was 0.935 for the whole group, with no baseline differences between groups (data not shown). Similarly, the waist circumference–hip circumference ratio did not change in the exercise groups but increased ($P<.05$, paired $t$ test) in the control group.

Figures 1 to 3 depict the effects of no regular exercise as well as the effects of different amounts and intensities of exercise on body weight, body composition, skinfolds, and circumferences. Again, a very clear, consistent,



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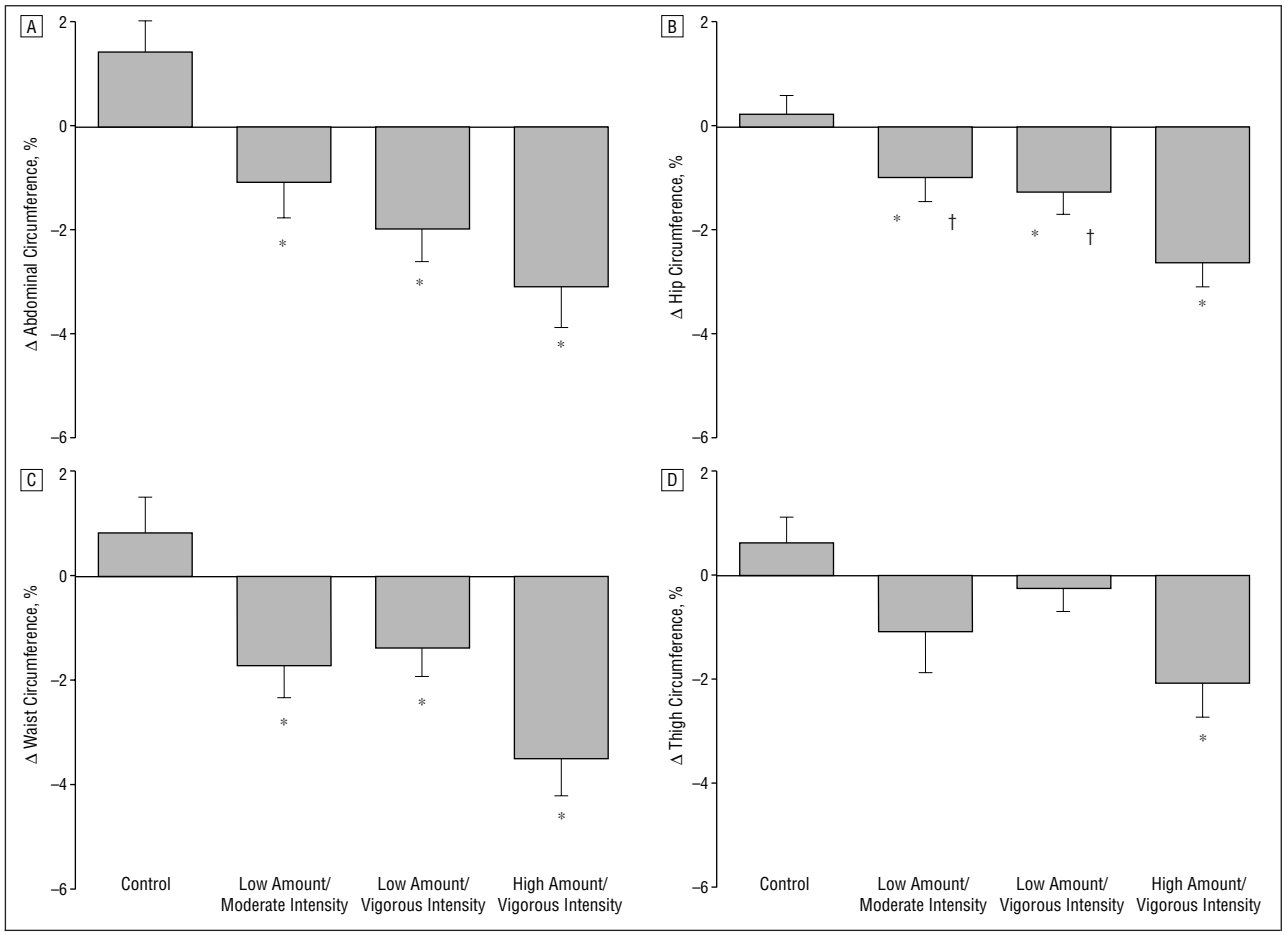


**Figure 3.** Effects of exercise amount and intensity on mean percent changes in circumferences: abdominal (A), hip (B), minimal waist (C), and thigh (D). The asterisk indicates $P<.05$ compared with controls; dagger, $P<.05$ compared with high-amount exercise group. Error bars show SE.

dose-response relationship between amount of exercise and the effect on each of these variables is evident. In all cases, except for lean body mass, the change score for the high-amount group was significantly improved compared with the controls. And in all cases, both low-amount exercise groups had a better effect on each of these 12 variables than the no exercise control group, with 8 of 12 of these comparisons being significant even after controlling for multiple comparisons. Finally, for many of these variables, the high-amount group had significantly better improvements than 1 or both of the low-amount groups (Figure 1-3). Specifically, the high-amount group had significantly better change scores than the low-amount/moderate-intensity group on weight change, percent lean body mass, fat mass, skinfolds (abdominal, suprailiac, and thigh), and hip circumference. And the high-amount group had significantly better improvements than the low-amount/vigorous-intensity group on weight, percent lean body mass, fat mass, both abdominal and thigh skinfolds, and hip circumference.

While the effect of exercise amount was very clear, the effect of exercise intensity was less clear. There appeared to be an effect of exercise intensity on several variables, especially on lean body mass. However, there were no variables for which the low-amount/vigorous-intensity group was significantly better than the low-amount/moderate-intensity group (all $P$ values $>.20$). The low-amount/vigorous group had a nearly 2-fold greater increase in lean body mass than the controls ($P<.05$), but after correction for multiple comparisons, this $P$ value was not significant. The high-amount group had about the same increase in lean body mass but nearly twice as large of decrease in body fat, which may explain its relatively large decrease in thigh circumference.

In **Figure 5**, the clear dose-response relationship between amount of exercise and amount of weight change is evident. The nearly linear relationship suggests that sedentary overweight individuals may need to accumulate the equivalent of 6 to 7 miles (9.6-11.2 km) of walking or jogging each week just to prevent weight gain ($x$-intercept is between 5.7 miles [9.1 km]/wk and 6.75 miles [10.8 km]/wk, depending on whether a linear or second-order polynomial equation is fitted to the data). However, the $x$-intercept is only an estimate of the average weight change, and this estimate has not been directly tested. Also, the $x$-intercept describes an estimate of the amount of exercise that would result in half of the subjects gaining weight and half losing weight. A higher minimal level would be expected to result in increasingly greater percentages of subjects who experience weight loss. Overall, the relationship suggests that a very modest amount of exercise may prevent weight gain and that more exercise can lead to incrementally greater weight loss even with no decrease in calorie intake. Interest-



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**Table 1. Baseline Characteristics of Total Group and After Randomization Into Groups***

| Variable | Total Group (n = 120) | Control (n = 37) | Low Amount/ Moderate Intensity (n = 28) | Low Amount/ Vigorous Intensity (n = 28) | High Amount/ Vigorous Intensity (n = 27) |
|---|---|---|---|---|---|
| Age, y | 52.8 (6.4) | 52.5 (7.5) | 53.4 (5.0) | 52.7 (7.6) | 52.7 (4.8) |
| Weight, kg | 87.6 (13.9) | 88.0 (12.8) | 87.7 (17.3) | 88.0 (14.0) | 85.6 (11.5) |
| BMI | 29.7 (3.2) | 30.2 (3.3) | 29.9 (3.6) | 29.9 (3.2) | 28.9 (2.4) |
| Race, No. | | | | | |
| White | 94 (78.3%) | 28 | 21 | 21 | 24 |
| African American | 25 (20.8%) | 9 | 7 | 7 | 2 |
| Asian | 1 (0.8%) | 0 | 0 | 0 | 1 |
| Female/male | 55/65 | 18/19 | 13/15 | 12/16 | 12/15 |
| Food intake, kcal/d | 2122 (649) | 2091 (539) | 2138 (760) | 2021 (707) | 2228 (573) |
| CHO, %† | 48.8 (10.3) | 51.0 (9.6) | 48.5 (11.4) | 47.7 (9.0) | 48.0 (11.1) |
| Fat, % | 33.8 (8.4) | 32.2 (8.4) | 33.9 (8.3) | 35.5 (7.7) | 33.7 (9.1) |
| Protein, % | 15.8 (5.4) | 15.4 (3.6) | 15.9 (7.8) | 15.8 (4.0) | 16.2 (5.0) |
| Prescription and actual exercise amount | | | | | |
| Intensity, % peak $\dot{V}O_2$ | NA | NA | 40-55 | 65-80 | 65-80 |
| Prescription amount, miles/wk‡ | NA | NA | 12 | 12 | 20 |
| Prescription time, min/wk | NA | NA | 200 (44) | 127 (32) | 204 (40) |
| Adherence, % | NA | NA | 90.5 (10.7) | 90.1 (10.5) | 86.2 (11.7) |
| Actual amount, miles/wk§ | NA | NA | 10.9 | 10.8 | 17.2 |
| Actual time, min/wk‖ | NA | NA | 179 (37) | 114 (29) | 175 (36) |
| Frequency, sessions/wk | NA | NA | 3.6 (0.5) | 3.0 (0.5) | 3.8 (0.8) |
| Change scores (postvalue – prevalue) | | | | | |
| Calorie intake, kcal/d | NA | –75.7 (469) | –146.4 (655) | –22.4 (744) | –45.1 (575) |
| CHO intake, % | NA | –1.0 (10.2) | 0.6 (11.1) | –0.7 (11.2) | –0.1 (7.7) |
| Fat intake, % | NA | 0.3 (8.7) | –1.4 (7.8) | 0.7 (10.6) | 1.9 (7.5) |
| Protein, % | NA | 0.5 (6.3) | 0.8 (8.8) | –0.0 (4.9) | –1.6 (4.8) |

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); CHO, carbohydrate; NA, not applicable; $\dot{V}O_2$, peak oxygen consumption.

*Values are mean (SD) (except for variables with means or ranges only). There were no significant group differences in any demographic characteristic.

†Percentages from CHO, fat, and protein do not total 100% because calories from ethanol are not included.

‡Prescription amount is presented as the approximate number of miles per week that are calorically equivalent to the prescribed kilocalories per week of 14 kcal/kg for the low-amount exercise groups and 23 kcal/kg for the high-amount exercise group.

§Actual amount = prescription amount × adherence for each group (therefore no SD).

‖Actual time = prescription × adherence for each subject.

ingly, 27 (73%) of the 37 controls gained weight, while in the low-amount/moderate, low-amount/vigorous, and high-amount/vigorous exercise groups, 21 (75%) of 28, 20 (71%) of 28, and 23 (85%) of 27, respectively, lost weight.

## COMMENT

We report herein data from the first prospective, randomized controlled study, to our knowledge, to investigate the effects of different amounts of exercise on body weight, body composition, and measures of central adiposity in overweight and obese individuals. This is also the first study designed to investigate the separate and combined effects of exercise amount and exercise intensity on these variables. We believe the most important finding in the present study was the clear, dose-response relationship observed between the amount of weekly exercise and the amount of weight change in overweight individuals (Figure 5). This occurred even in the absence of reduced caloric intake. This dose-response relationship leads to a number of subsequent conclusions. The fact that the controls gained weight while both low-amount groups lost weight indicates that the controls were, on average, in sustained positive energy balance and that a relatively small amount of exercise can reverse this condition, resulting in a sustained negative energy balance. This finding supports the theory that weight gain, as experienced by the controls in this study, is likely due to a small daily imbalance in caloric intake[15] over energy expenditure. Further, it simultaneously offers a specific exercise prescription that resulted in weight maintenance or weight loss in 73% of the overweight or mildly obese individuals in this study. Most individuals can achieve this amount of exercise by performing an activity such as brisk walking for 30 min/d or a vigorous exercise such as jogging for 20 min/d. Finally, the relatively linear relationship between amount of exercise and weight change, combined with the finding that weight gain occurs below a certain level of physical activity, provides strong support for the hypothesis that a minimal amount of physical activity is necessary for appropriate weight maintenance, which was first proposed by Mayer et al.[16,17] It would seem likely that many in our American society may have fallen below this minimal level of physical activity required to maintain body weight.

A second important finding of this study was that 4 independent measures of central obesity (abdominal and suprailiac skinfolds and minimal waist and abdominal circumferences) demonstrated a strong dose-response relationship between the amount of weekly exercise and the improvements in these measures. The importance of central body fat as an independent risk factor for cardiovas-



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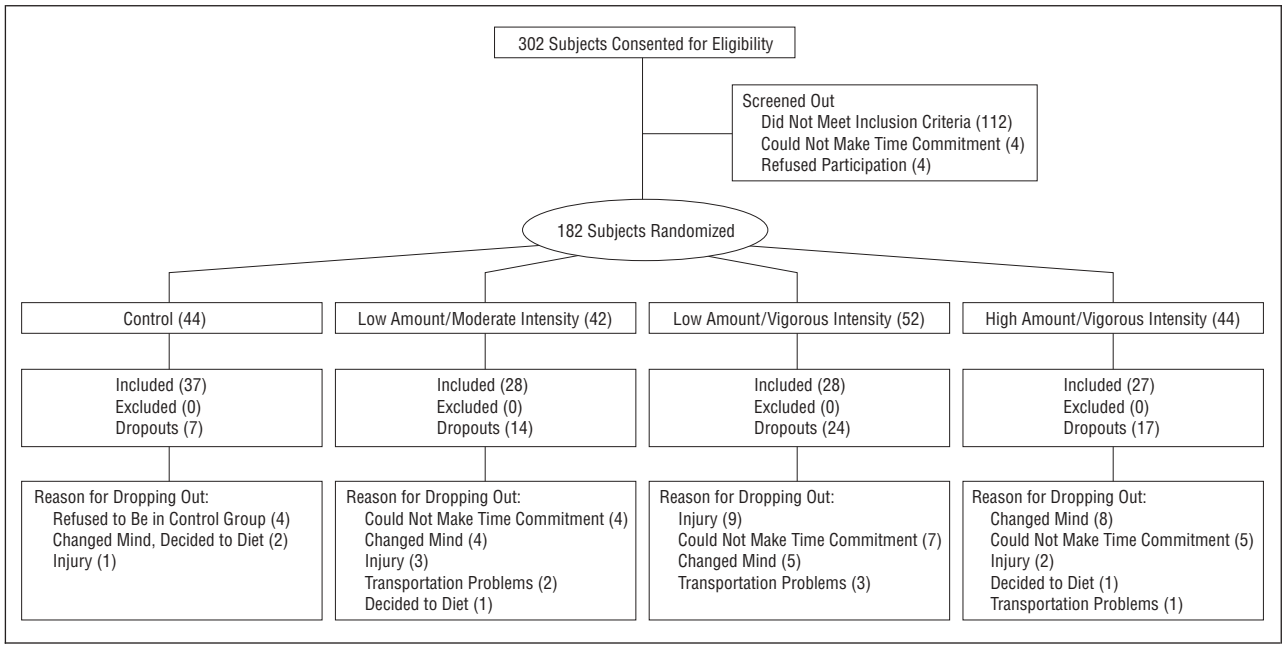


**Figure 4.** Flowchart of screening and randomization inclusions and exclusions.

**Table 2. Effects of Amount and Intensity of Exercise Training on Total Body Mass, Fat and Lean Body Mass, Skinfolds, and Circumferences***

| | Control (n = 37) | | Low Amount/ Moderate Intensity (n = 28) | | Low Amount/ Vigorous Intensity (n = 28) | | High Amount/ Vigorous Intensity (n = 27) | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Baseline** | **Change** | **Baseline** | **Change** | **Baseline** | **Change** | **Baseline** | **Change** |
| Body mass, kg | 87.5 (12.8) | 1.1 (2.1)‡ | 88.7 (17.3) | −1.3 (2.2)† | 88.0 (14.0) | −1.1 (2.0) | 85.6 (11.5) | −3.5 (2.8)‡ |
| Body fat mass, kg | 31.2 (7.1) | 0.5 (2.8) | 29.9 (9.7) | −2.0 (2.7)‡ | 29.6 (7.3) | −2.6 (3.4)‡ | 29.0 (6.0) | −4.9 (3.0)‡ |
| Body fat, % | 35.8 (6.7) | 0.1 (2.8) | 33.6 (7.7) | −1.7 (2.8)‡ | 33.7 (6.7) | −2.6 (3.5)‡ | 34.1 (6.8) | −4.7 (3.3)‡ |
| Lean body mass, kg | 56.1 (10.3) | 0.6 (2.2) | 58.9 (13.1) | 0.7 (2.7)† | 58.4 (11.4) | 1.5 (2.7)‡ | 56.4 (10.6) | 1.4 (2.7)‡ |
| Lean body mass, % | 63.8 (6.5) | −0.0 (2.9) | 66.5 (7.6) | 1.9 (2.7)‡ | 66.1 (6.6) | 2.7 (3.5)‡ | 65.6 (6.7) | 4.7 (3.3)‡ |
| Skinfolds, mm | | | | | | | | |
| Abdominal | 45.2 (7.9) | 0.0 (6.2) | 40.2 (11.6) | −2.1 (7.3) | 40.9 (9.2) | −4.2 (9.4)† | 41.4 (10.2) | −8.0 (8.0)‡ |
| Suprailiac | 34.7 (8.8) | 0.4 (7.9) | 32.6 (9.9) | −4.1 (6.6)‡ | 33.4 (9.7) | −5.0 (7.3)‡ | 31.0 (9.7) | −7.0 (5.1)‡ |
| Thigh | 39.2 (14.9) | 0.2 (5.1) | 35.1 (17.4) | −2.1 (4.9)† | 35.9 (16.1) | −3.1 (6.9)† | 36.1 (15.4) | −6.6 (5.4)‡ |
| Tricep | 29.6 (10.3) | −0.7 (4.4) | 28.1 (10.1) | −3.0 (5.7)‡ | 27.0 (10.7) | −2.9 (4.8)‡ | 29.8 (10.4) | −5.4 (6.1)‡ |
| Fat distribution | | | | | | | | |
| Central skinfold, % | | 1.4 (17.3) | | −6.8 (16.2)† | | −10.6 (20.2)‡ | | −20.7 (15.5)‡ |
| Peripheral skinfold, % | | 0.1 (11.6) | | −8.1 (12.9)† | | −9.9 (17.1)‡ | | −17.2 (13.8)‡ |
| Circumferences, cm | | | | | | | | |
| Abdominal | 104.0 (9.7) | 1.4 (3.7)† | 103.6 (11.0) | −1.1 (3.7) | 103.4 (9.9) | −2.0 (3.6)‡ | 101.0 (9.0) | −3.2 (4.1)‡ |
| Minimal waist | 95.2 (9.3) | 0.8 (4.2) | 96.6 (11.6) | −1.6 (3.1)‡ | 94.5 (9.8) | −1.4 (2.8)† | 95.2 (9.9) | −3.4 (3.4)‡ |
| Hips | 111.7 (7.5) | 0.1 (2.6) | 110.4 (8.7) | −1.1 (2.8) | 109.7 (7.5) | −1.4 (2.5)‡ | 108.4 (4.6) | −3.0 (2.7)‡ |
| Thigh | 59.6 (5.7) | 0.3 (1.9) | 60.1 (5.6) | −0.7 (2.6) | 59.9 (5.2) | −0.2 (1.7) | 58.5 (3.5) | −1.2 (2.1)‡ |
| Waist-hip ratio, % | | 1.3 (3.8)† | | −0.1 (3.5) | | −0.7 (3.6) | | −0.3 (3.9) |

*Values are mean (SD). Analysis of variance revealed no significant baseline differences between groups.
†$P<.05$, postvalue compared with prevalue (paired *t* test, 2-tailed).
‡$P<.01$, postvalue compared with prevalue (paired *t* test, 2-tailed).

cular disease, type 2 diabetes mellitus, and hypertension is well established.[3-5] While not always statistically significant, the highest exercise amount always resulted in larger reductions in abdominal and suprailiac skinfolds and in minimal waist and abdominal waist circumferences compared with the 2 groups performing lower amounts of exercise, which in turn always resulted in larger reductions in these measures compared with the controls. We did not, however, find that exercise resulted in a preferential decrease in central vs peripheral markers of body fat. Some studies have shown a preferential decrease in central obesity in older,[18,19] but not younger,[19] individuals. Further research is needed in this area.

By comparing the 2 low-amount groups, there was an indication that higher exercise intensity resulted in a greater increase in lean body mass compared with lower



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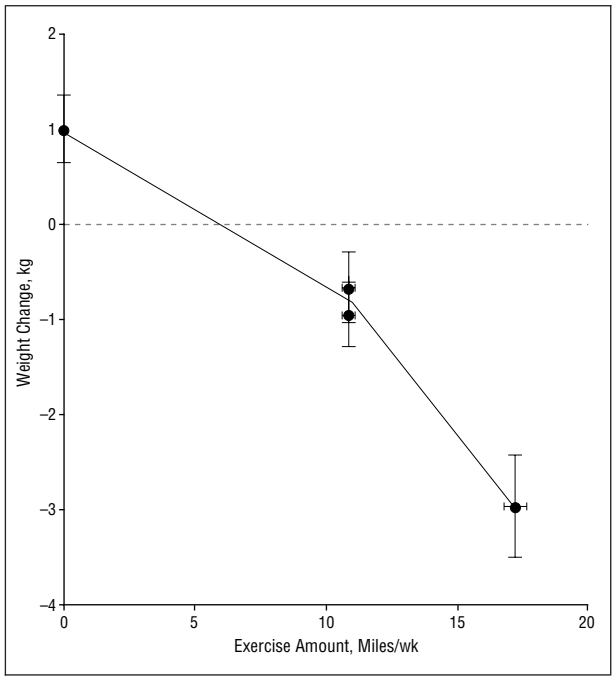


**Figure 5.** The relationship between mean amount of weight change and amount of exercise. Error bars show SE.

exercise intensity. While these differences were not statistically significant, both high-intensity exercise groups had greater increases in lean body mass compared with the controls ($P<.05$ before, but not after, correction for multiple comparisons), whereas the low-intensity group was not different from the controls. In addition, both vigorous-intensity exercise groups had almost identical increases in lean body mass. If confirmed, this finding would have significant ramifications, suggesting that while exercise amount determines total body weight change and fat mass loss, exercise intensity would appear to be the primary determinant of gain in lean body mass. The effect of exercise intensity on fat mass has long been a popular but controversial topic with many opposing theories, but few, if any, randomized controlled studies exist. In the present study, we found that the effect of exercise intensity on fat mass loss was small and nonsignificant, whereas exercise amount had a much clearer effect.

The fact that there was an effect of exercise amount on weight change should not be surprising. Although reviews on the subject suggest that exercise results in only modest weight loss,[20,21] the important effect of the amount of weekly exercise has not been examined carefully. As pointed out by Ross et al,[22] many of the studies reviewed have used modest exercise training amounts and as a result, modest effects should have been expected. In fact, as the present study suggests, the first 6 to 7 miles (9.6-11.2 km) of exercise per week may be necessary just to prevent further weight gain. There have been several studies that have used much larger amounts of exercise and have found correspondingly larger weight losses.[4,22-25] For example, in the study by Lee et al,[24] 5 months of basic military training resulted in an average body mass loss of 12.5 kg in 17- to 19-year-old obese male recruits. One of the landmark studies in this area was by Ross et al,[22] who for the first time compared an exercise amount that was designed to increase energy expenditure by the same number of kilocalories as the diet intervention decreased energy consumption (ie, 700 kcal/d). They found identical weight loss (ie, both groups lost 7.5 kg [8%] of body weight), with the exercise group losing significantly more fat mass than the diet group. These studies and the present study indicate that, with regard to exercise, weight change is all about the degree of caloric imbalance created through the exercise program.

The observed relationships between exercise amount and weight loss, body composition changes, and decreases in measures of central adiposity, all provide important additional information with regard to the optimal and/or minimal amounts of exercise required to achieve a particular effect. We are not able to suggest an optimal amount of exercise, since there was no indication that the beneficial effects of exercise on weight loss were diminishing at the highest exercise amount studied (Figure 5). However, the high amount of weekly exercise (caloric equivalent of 17 miles [27.2 km]/wk) resulted in a combined (gain by controls – loss by exercise groups) –4-kg body mass change, a –5.2-kg fat mass change, and a –4.6-cm (almost 2-in) reduction in the abdominal waist circumference compared with what would have occurred without exercise. This amount of exercise also corresponded with widespread and significant improvements in lipoproteins and lipoprotein subfractions[26] as well as with short- and long-term improvements in insulin sensitivity and fasting plasma glucose,[27] as recently reported from our group. This amount of exercise can be achieved by most sedentary individuals (81% in this study) by accumulating approximately 3.5 hours of vigorous intensity exercise per week. However, it is important to understand that the amount of time required to accumulate the equivalent of approximately 17 to 18 miles (27.3-28.8 km)/wk varies based on fitness levels. For this reason, to get the exercise stimulus used in this study, we recommend that total amount of activity be the goal rather than a certain amount of time per week.

With regard to the minimal dose, the *x*-intercept of the observed relationship (Figure 5), although not directly tested, suggests that an exercise amount calorically equivalent to approximately 6 to 7 miles (9.6-11.2 km) of exercise per week may prevent further weight gain in overweight sedentary individuals. In the present study, the amount of exercise (approximately 11 miles [17.6 km]/wk) that resulted in modest weight loss required considerably less than the 77 to 80 min/d (approximately 560 min/wk) of moderate-intensity exercise that was estimated by studies using doubly labeled water techniques[8,28] and is also much less than the recent recommendation of 60 min/d as necessary for weight maintenance.[10] As previously mentioned, the lower exercise amount used in this study can be achieved by most individuals (79% in this study) by performing moderate-intensity exercise for 30 min/d or by vigorous-intensity exercise such as jogging for 20 min/d.

There are 2 important differences between the present study and the doubly labeled water studies.[8,28] First, both of the doubly labeled water studies involved women who had recently lost more than 10 kg of weight and therefore were at a much higher risk of weight regain. The sub-



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jects in the present study were overweight and had not recently lost a large amount of weight. Second, it is important to realize that the doubly labeled water studies were not exercise studies. That is, they did not actually test the hypothesis that 77 to 80 minutes of exercise would prevent weight regain. Pavlou et al[29] found that an amount of exercise that approximated 1500 kcal/wk was adequate to prevent weight regain in men who had previously lost an average of 12 kg by diet plus exercise. Also, in a study by Jakicic et al,[30] it was shown that in women who lost weight through 6 months of diet and exercise, those who averaged approximately 280 min/wk (40 min/d) maintained their weight loss over an additional 12 months. Forty minutes per day is a substantial amount of activity (almost 5 h/wk), but it is still far short of the hypothesized but not tested 77 to 80 min/d.

## CONCLUSIONS

The major finding of the present study was that there was a clear dose-response relationship observed between amount of weekly exercise and amount of weight change. This is not surprising, since this study and other carefully conducted investigations[16,17,22] show the issue is simply one of energy balance for control of weight. This relationship, coupled with the finding that the controls gained weight while a fairly modest amount of exercise led to weight loss, provides strong support for the Mayer hypothesis that a minimal amount of physical activity is necessary for appropriate weight control.[16,17] The data imply that the minimal level may be as low as 6 miles (9.6 km) of walking (or other equivalent caloric expenditure) per week. Additionally, this study revealed a clear dose-response effect between amount of weekly exercise and decreases in measurements of central obesity and total body fat mass, reversing the observed effects in the control (nonexercising) group. The close relationship between central body fat and total fat and cardiovascular disease, diabetes, and hypertension lends further importance to this finding. Our findings suggest that a modest amount of exercise can prevent weight gain with no changes in diet, and more exercise may lead to important weight loss in initially overweight individuals.

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*From the Divisions of Cardiology (Drs Slentz, Duscha, and Kraus, Mss Johnson and Aiken, and Mr Ketchum), Geriatric Medicine (Dr Bales), and General Internal Medicine (Dr Samsa), Department of Medicine, Duke Center for Living (Dr Kraus), Center for Health Policy Research (Dr Samsa), and Department of Community and Family Medicine (Dr Samsa), Duke University Medical Center, Durham, NC; and Geriatric Research, Education and Clinical Center (Dr Bales), Durham Veterans Affairs Medical Center, Department of Exercise and Sports Science and Human Performance Laboratory, East Carolina University, Greenville, NC (Dr Houmard).*

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*Corresponding author and reprints: Cris A. Slentz, PhD, Division of Cardiology, Department of Medicine, PO Box 3022, Duke University Medical Center, Durham, NC 27710 (e-mail: Cris.Slentz@duke.edu).*

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