

# Strength training and adiposity in premenopausal women: Strong, Healthy, and Empowered study<sup>1-4</sup>

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## ABSTRACT

**Background:** American women aged 25–44 y gain 0.5–1 kg yearly, most of which is fat. Because few midlife women participate in strength training, this mode of activity may be a novel intervention for preventing age-associated fat increases in this population.

**Objectives:** The primary aim was to assess the efficacy of twice-weekly strength training to avoid increases in percentage body fat and intraabdominal fat.

**Design:** A randomized controlled trial was conducted in an ethnically diverse sample of 164 overweight and obese [body mass index (in kg/m<sup>2</sup>): 25–35] women aged 25–44 y. The treatment group did twice-weekly strength training for 2 y. The standard care comparison group was given brochures recommending aerobic exercise. Assessments at baseline, 1, and 2 y included intraabdominal fat by computed tomography scan and body fat and fat-free mass by dual-energy X-ray absorptiometry.

**Results:** During 2 y, percentage body fat changes were  $-3.68 \pm 0.99\%$  for the treatment group and  $-0.14 \pm 1.04\%$  for the control group,  $P = 0.01$ . Two-year intraabdominal fat changes were  $7.05 \pm 5.07\%$  for the treatment group and  $21.36 \pm 5.34\%$  for the control group,  $P = 0.05$ .

**Conclusion:** This study suggests that strength training is an efficacious intervention for preventing percentage body fat increases and attenuating intraabdominal fat increases in overweight and obese premenopausal women. This is relevant to public health efforts for obesity prevention because most weight gain can be assumed to be fat, including abdominal fat. *Am J Clin Nutr* 2007;86:566–72.

**KEY WORDS** Strength training, visceral fat, exercise, women, body composition, obesity

## INTRODUCTION

American women aged 25–44 y typically gain 0.5–1 kg yearly (1, 2). These gains contribute to the increase in obesity prevalence with increasing age (3) and can be assumed to be mostly fat (4, 5). Body weight and body mass index (BMI; in kg/m<sup>2</sup>) are commonly used as surrogates of body fatness for ease of measurement and reporting. However, it is well established that excess fat mass, particularly intraabdominal fat mass, links obesity to excess rates of morbidity and mortality (6). Therefore, behavioral interventions to reduce or prevent increases in body fat, particularly intraabdominal fat, may be useful for reducing the high costs of obesity (7).

Physical activity is noted to be associated with reductions in body fat (8–11), as well as important health benefits independent

of body fatness (12). Numerous intervention trials have shown that aerobic exercise controls or reduces intraabdominal fat (13–16). We have previously shown that twice-weekly strength training is feasible during 9 mo in women and that this program decreased percentage body fat (17). However, the effect of this intervention on intraabdominal fat has not been explored, and a longer study was needed to assess the sustainability of the previously observed changes to percentage body fat. We hypothesized that strength training would be particularly useful in the context of preventing body fat increases because it would increase muscle mass and prevent the muscle loss that occurs with aging, as well as associated decreases in resting energy expenditure (18, 19). This may be particularly useful in the context of avoiding sarcopenic obesity with aging. The improvements in muscle strength and endurance from strength training may also allow women to feel more comfortable being physically active in a variety of domains (eg, recreation, transportation, and household).

The primary objectives of the Strong, Healthy, and Empowered (SHE) study were to assess the efficacy of twice-weekly strength training to prevent increases in percentage body fat and intraabdominal body fat compared with a standard care comparison group among women. These objectives were accomplished in a 2-group randomized controlled trial.

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## SUBJECTS AND METHODS

Volunteers were recruited from the Minneapolis-St Paul area between July 2002 and June 2003. Recruitment strategies included advertisements in print and broadcast media, flyers, and direct mailings. Advertisements in black media outlets facilitated targeted recruitment of African American women. Eligibility criteria included ages of 25–44 y inclusive, BMI of 25–35 inclusive with stable body weight (<10% change during the past year), premenopausal status, sedentary or only modestly physically active ( $\leq 3$  weekly sessions of moderate aerobic physical activity), and nonsmoker. Exclusion criteria included participation in a weight-loss program, physician-diagnosed menstrual irregularities or significant gynecologic conditions, any positive response on the Physical Activity Readiness Questionnaire (20), history of strength training in the past 6 mo, medical conditions or medications that could limit participation in the exercise program or affect study measurements (including cholesterol-lowering medications, psychiatric medications at dosages known to alter weight, appetite suppressants), currently or recently pregnant, currently or recently lactating, uncontrolled hypertension (systolic > 160 or diastolic > 99), history of cancer within the past 5 y, or plans to be out of town for >3 consecutive weeks during the study. The study protocol was approved by the University of Minnesota Institutional Review Board.

Within each recruitment wave ( $n = 40$ ), randomization was stratified to balance the groups by age (25–34 y compared with 35–44 y) and percentage body fat (above compared with below the median). A study staff member blinded to treatment status performed the randomization procedures.

### Intervention

Treatment group participants were provided with a 2-y membership to the Minneapolis Young Women's Christian Association (YWCA) fitness centers. The intervention started with 16 wk of twice-weekly sessions supervised by certified fitness professionals (ratio of participants to trainers  $\leq 6:1$ ). During this supervised intervention, participants were taught stretches, warming up, cooling down, and abdominal and low back–strengthening exercises (for injury prevention). The first circuit of strength-training exercises used isotonic variable resistance machines. Free-weight exercises were introduced over time. All weight-training circuits included 8–10 exercises to work the quadriceps, hamstring, gluteal, pectoral, erector spinae, latissimus dorsi, rhomboid, deltoid, biceps, and triceps muscles. By the end of the first month, the 1-h sessions included 3 sets of 8–10 repetitions for each exercise. The weight lifted was progressively increased during year 1. During year 2, subjects reduced the circuits to 2 sets per exercise and maintained the highest weight lifted for each exercise, resulting in a session length of  $\approx 45$  min.

The behavioral aspects of the strength-training intervention were guided by social cognitive theory (21). Throughout the 2-y intervention, the fitness trainers made weekly reminder calls to participants who had not completed 2 sessions. Two hours of free childcare per session were provided. After the first 16 wk, trainers led booster sessions every 12 wk, during which new exercises were introduced. Otherwise, participants exercised unsupervised. The fitness trainers were available by phone or e-mail and at the gym. Other intervention components included semiannual social gatherings, a study website, and a monthly newsletter.

Participants in the treatment group were asked to maintain whatever amount of aerobic activity they had been doing before study entry ( $\leq 3$  times weekly, according to eligibility criteria) throughout the study period.

Women randomly assigned to the standard care comparison group were mailed American Heart Association brochures that recommended 30 min of moderate intensity activity on most days of the week, consistent with current public health recommendations (12). The advice in those brochures focused mostly on starting a walking program. The comparison group subjects were not included in any of the social support components of the intervention or provided any exercise guidance beyond the 2 brochures.

Regardless of group assignment, participants were asked not to make any changes in their diets that might result in weight or fat gain or loss. Seasonal variations in their diets were expected and allowed. This message was communicated during recruitment, included in the consent document, and reiterated during measurement visits and strength-training sessions.

### Data collection

All assessments occurred at baseline, 1 y, and 2 y. The measurement staff was blinded to group assignment (blinding success was not assessed). Measurements were completed with the use of standard written protocols. Body weight and height were assessed on a digital scale and scale-mounted stadiometer (Scaletronix 5005; Scale-tronix, White Plains, NY). Body composition was measured by dual-energy X-ray absorptiometry (DXA) with the use of the Lunar Prodigy DXA apparatus (Lunar Radiation Corp, Madison, WI). The DXA measurements used a standard protocol and were conducted by a trained technician. Reproducibility with the instrument used is  $0.6\% \pm 0.5\%$  for fat and lean mass (22). Monthly calibration was completed with manufacturer phantoms. No significant machine drift was noted during the study period.

Abdominal fat areas (total, subcutaneous, and intraabdominal) were estimated from a single-slice computed tomography (CT) scan at the L2–L3 interspace. The methods used for CT analysis were described elsewhere (23). No significant machine drift was noted during the study period; the scanner was calibrated weekly.

Muscle strength was assessed with the maximum weight that was lifted once on the bench press and the leg press with the use of previously described procedures (17). This testing was repeated in 2 appointments within a 2-wk period at each measurement time point to ensure the best possible effort. The best of the 2 measures was used for analysis.

Physical activity was assessed at each measurement time point with the use of an accelerometer (model 7164, version 2.2; Actigraph LLC, Fort Walton, FL), worn for at least 4 d (2 weekdays and 2 weekend days) during waking hours, except when the subject was in contact with water (ie, showering, swimming). A treadmill test was completed to determine the threshold accelerometer count above which activity could be counted as nonsedentary. Subjects walked on a treadmill for 7 min at 2 miles/h, and the mean accelerometer counts per minute from those 7 min were calculated to determine the threshold for nonsedentary activity. The physical activity level reported is the number of minutes spent above this individually determined threshold, with weekdays and weekend days weighted to reflect a 1-wk period. This approach is consistent with best practices guidelines (24).

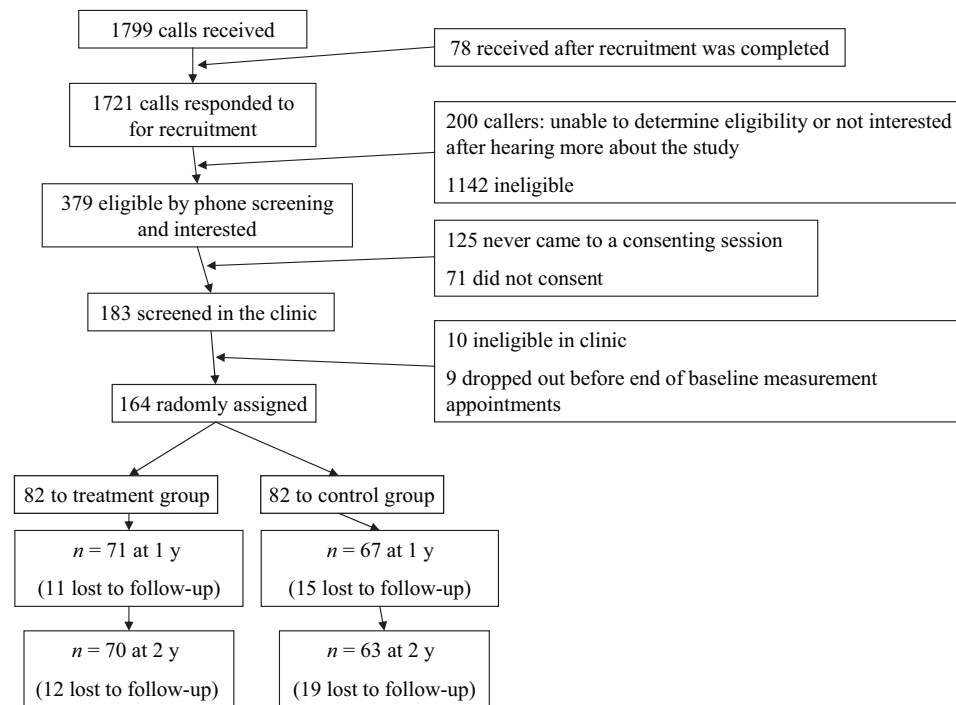


FIGURE 1. Flow of participants through the study.

Adherence to strength training was assessed by dividing the number of strength-training sessions attended (according to participant exercise logs kept at the YWCA and checked weekly by fitness trainers) by the total possible sessions for a given time period. The total number of possible sessions per year was 102 (twice weekly for 51 wk, 1 wk off/y).

The Diet History Questionnaire (DHQ), a food-frequency questionnaire, was used to estimate usual intake from diet and nutrient supplements from the prior year (25). A prior study noted a correlation between the DHQ and three 24-h recalls of  $r = 0.48$  among women (26). Additional measures completed for the SHE study included standardized interviewer-administered surveys for demographics, including self-reported race or ethnicity, education, marital status, and number and ages of children living at home. Race or ethnicity categories were the same as in the 2000 US Census. Because there were few participants in race or ethnic categories other than white or black, women reporting Asian, Native American, or other ethnicities were grouped as other.

### Sample size

With type I error for 2-sided testing split over the 2 major outcomes (2.5% for each), power analysis showed that 64 women per group would provide 90% power to detect the intervention effect for percentage body fat achieved in the pilot study ( $-1.63\%$ ), with an effect size of 0.2. Power analysis for intra-abdominal fat relied on unpublished variance data from our laboratory and showed that 71 women per group would yield 85% power to detect an effect size of 0.3 (MD Jensen, KH Schmitz, unpublished observations, 2000). We recruited 82 women per group to allow for some dropouts.

### Statistical analysis

Descriptive statistics by group were generated by cross-tabulation for categorical variables and by means for continuous

measures. Testing of group differences at baseline was by chi-square tests or independent  $t$  tests. Differences within group during 2 y (longitudinal changes from baseline) were tested by repeated measures analysis of variance. For body size and strength-training improvements, changes during 2 y were assessed as the percentage of the baseline measure. Percentage rather than absolute changes were used to assess intervention effects on strength and body size to address the potential of inappropriately equating relatively large differences in small women and relatively small differences in large women.

Analysis models used repeated measures analysis of covariance, adjusting for race or ethnicity (categorical), baseline activity (minutes per week above threshold activity), marital status, and kilocalorie intake. Specific single df contrasts of adjusted mean percentage changes were generated to address specific hypotheses (eg, net group differences at 2 y compared with baseline). We present  $P$  values for year 2 only; the changes at year 1 are presented for information only. Anyone wanting to control for multiple tests can easily use the Bonferroni method to multiply the  $P$  values by the number of tests being considered. All analyses were conducted with the use of SAS (version 8.2; SAS Institute, Cary, NC).

### RESULTS

Flow of participants through the study is presented in **Figure 1**. An attempt was made to screen 1721 women. The most common reason for ineligibility was body size outside the eligible range. The most common reason for not being interested was lack of willingness to be randomly assigned. At baseline, 164 women were randomly assigned into 2 equal-sized groups. Loss to follow-up overall was 19% by the end of the 2-y study. Loss to follow-up differed by treatment status (23.2% in the comparison group compared with 14.6% in the treatment group at 2 y) but not

**TABLE 1**  
Description of participants<sup>1</sup>

Variable	Baseline (n = 164)		Year 1 (n = 138)		Year 2 (n = 133)	
	Treatment (n = 82)	Control (n = 82)	Treatment (n = 71)	Control (n = 67)	Treatment (n = 70)	Control (n = 63)
Age (y)	36 ± 5 <sup>2</sup>	36 ± 6	37 ± 6	36 ± 6	37 ± 5	36 ± 6
Ethnicity						
Black [n (%)]	24 (29)	22 (27)	19 (27)	17 (25)	19 (27)	16 (25)
Other [n (%)] <sup>3</sup>	10 (12)	10 (12)	9 (13)	9 (13)	8 (11)	7 (11)
White [n (%)]	48 (59)	50 (61)	43 (61)	41 (61)	43 (61)	40 (63)
College degree (%)	73	65	70	67	70	68
Married (%)	50	45	48	50	54	51
With children <5 y old (%)	57	56	54	55	53	52
Energy intake (kcal)	2036 ± 916	2163 ± 1014	1919 ± 893	1862 ± 686	1926 ± 827	1939 ± 942
Physical activity <sup>4</sup>	630 ± 372	544 ± 320	584 ± 325	538 ± 307	611 ± 337	602 ± 442

<sup>1</sup> No differences were noted between groups at any time point or within groups across time for any variables,  $P > 0.15$  for all comparisons. Comparisons of continuous variables were made with  $t$  tests; comparisons of categorical variables were made with chi-square tests.

<sup>2</sup>  $\bar{x} \pm SD$  (all such values).

<sup>3</sup> Includes Asian, Native American, and Pacific Islanders.

<sup>4</sup> Units are minutes above threshold per week. Threshold was an individually calibrated average accelerometer count per minute while walking at 2 miles/h on a treadmill for 7 min. Therefore, the physical activity variable reflects minutes spent doing any activity of an intensity  $\geq$  walking 2 miles/h, averaged over a 1-wk period.

by ethnicity (black compared with white) or by baseline BMI status (25–29.9 compared with 30–35).

Participant characteristics at all 3 measurement time points are shown in **Table 1**. No differences were observed between groups at any time point, and no between-group differences were noted for 1- or 2-y changes in any of the variables presented in Table 1. Women included in the right-most column of Table 1 were those who completed the CT scan measurements at year 2. These women formed the cohort included in the statistical analyses resulting in the remaining tables.

The adherence data for the participants in the strength-training treatment group are given in **Table 2**. Adherence was highest during the supervised intervention period (data not shown). Average adherence was 76% in year 1 and 61% in year 2, for an overall mean of 71% during the full 2 y. Adherence was lower in year 2 compared with year 1 ( $P < 0.0001$ ).

The maximum kilograms lifted once in bench press and leg press at baseline and the percentage changes over time are shown in **Table 3**. The maximum that could be lifted once at baseline was  $\approx 40$  kg for bench press and 130 kg for leg press. During 2 y, the net treatment effect for bench and leg presses were 9.4% and 9.7%, respectively.

**TABLE 2**  
Adherence to the protocol of twice-weekly strength training

	Baseline to year 1 (n = 82)	Year 1 to year 2 (n = 71)	Baseline to year 2 (n = 71)
Adherence ( $\bar{x}$ )	76	61 <sup>1</sup>	71
Attendance			
0–20%	1	14	0
21–40%	10	11	14
41–60%	16	21	20
61–80%	21	21	24
81–100%	52	33	42

<sup>1</sup> Mean adherence in year 2 was significantly lower than in year 1,  $P < 0.0001$  from mixed-model  $t$  test.

Body size at baseline and the percentage changes over time by treatment status are shown in **Table 4**. Despite the differential increases in strength according to treatment group shown in Table 3, lean body mass did not increase significantly during 2 y. Significantly larger decreases in percentage body fat and attenuation of intraabdominal fat increases were noted during 2 y, with net treatment effects (change in treatment group added to change in standard care group) of  $-3.5\%$  and  $-14.3\%$ , respectively. Treatment effects for total fat mass and subcutaneous abdominal fat area were marginally significant by 2 y.

## DISCUSSION

This 2-y strength-training intervention among an ethnically diverse sample of overweight and obese, premenopausal, previously sedentary women decreased percentage body fat and attenuated increases in intraabdominal fat. The decreases in body fat (total, percentage, and intraabdominal) in the treatment group were more evident after 1 y than at the end of the second year. This finding coincides with decreased protocol adherence during year 2 and the shift from intervention (year 1) to maintenance (year 2) phase. However, the increases in body fat (total, percentage, and intraabdominal) in the standard care control group were larger in year 2 than in year 1. As a result, larger between-group differences were noted at 2 y than at 1 y. This finding supports the potential for strength training to provide sustained obesity prevention benefits over time. These findings suggest that strength training is an efficacious mode of physical activity to expand the repertory of approaches available to women for the purpose of obesity prevention.

No net treatment effect was observed on total body weight. This was expected, because strength training primarily alters body composition (increasing muscle mass and reducing fat mass), and there was no dietary intervention. However, because fat mass (specifically intraabdominal fat) is the primary element of elevated body weight associated with chronic disease risk, the changes in these outcomes are of equal or greater importance to

**TABLE 3**Maximum weight lifted at baseline and change ( $\Delta$ ) during 1 and 2 y

	Baseline	$\Delta$ Baseline to year 1	$\Delta$ Baseline to year 2	$P^1$
		%	%	
Bench press				
Treatment group (kg) <sup>2</sup>	40.1 $\pm$ 0.82 <sup>3</sup>	9.85 $\pm$ 1.69	6.66 $\pm$ 1.69	0.0003
Control (kg) <sup>4</sup>	39.3 $\pm$ 0.86	-1.75 $\pm$ 1.84	-2.70 $\pm$ 1.80	
Leg press				
Treatment (kg)	130 $\pm$ 3.5	14.38 $\pm$ 2.95	13.2 $\pm$ 2.95	0.003
Control (kg)	131 $\pm$ 3.6	6.33 $\pm$ 3.16	3.48 $\pm$ 3.12	

<sup>1</sup> Values were derived from repeated-measures ANCOVA comparing changes during 2 y, adjusted for ethnicity, baseline physical activity, marital status, and kilocalorie intake at baseline and 2 ys.

<sup>2</sup>  $n = 82, 71,$  and  $70$  at baseline, year 1, and year 2, respectively.

<sup>3</sup>  $\bar{x} \pm SE$  (all such values).

<sup>4</sup>  $n = 82, 67,$  and  $63$  at baseline, year 1, and year 2, respectively.

changes in weight. Evidence suggests an association of excess abdominal fat and chronic disease risk across a wide range of BMIs (27). Evidence from cross-sectional and longitudinal studies show that the direct association of obesity with cardiovascular risk factors, morbidity, and mortality is strongest in those with disproportionately high intraabdominal fat (13, 28).

We hypothesized that strength training would be particularly useful in the context of preventing body fat increases because it would increase muscle mass and prevent the muscle loss that occurs with aging, as well as associated decreases in resting energy expenditure (18, 19). In light of our hypotheses, note that,

although the intervention did increase muscle strength, between-group comparisons of lean body mass increases did not reach statistical significance.

Aerobic exercise training consistently and preferentially reduces abdominal fat (6, 13–16). We are aware of 4 prior shorter studies that have used imaging technology to measure the changes in abdominal fat in response to strength training (29–32). Null findings in 17 nonobese young women (age: 18–35 y; BMI: <26) in response to 6 mo of strength training (30) are contrasted by 3 studies in older men and women that have shown preferential loss of trunk fat tissue as measured by DXA (31) or

**TABLE 4**Baseline body size measures and percentage change ( $\Delta$ ) from baseline at year 1 and at year 2 by treatment group

	Baseline	$\Delta$ Baseline to year 1	$\Delta$ Baseline to year 2	$P^1$
		%	%	
Body mass (kg)				
Treatment group <sup>2</sup>	81.6 $\pm$ 1.3 <sup>3</sup>	1.17 $\pm$ 0.79	1.72 $\pm$ 0.79	0.54
Control <sup>4</sup>	80.7 $\pm$ 1.3	0.88 $\pm$ 0.84	2.42 $\pm$ 0.84	
BMI (kg/m <sup>2</sup> )				
Treatment group	29.4 $\pm$ 0.4	1.07 $\pm$ 0.81	1.92 $\pm$ 0.81	0.74
Control	29.4 $\pm$ 0.4	0.85 $\pm$ 0.86	2.32 $\pm$ 0.86	
Body fat (%)				
Treatment group	44.3 $\pm$ 0.6	-4.36 $\pm$ 0.99	-3.68 $\pm$ 0.99	0.01
Control	43.5 $\pm$ 0.6	-2.26 $\pm$ 1.04	-0.14 $\pm$ 1.04	
Fat mass (kg)				
Treatment group	34.8 $\pm$ 0.9	-3.19 $\pm$ 1.66	-1.61 $\pm$ 1.66	0.07
Control	33.7 $\pm$ 0.9	-1.34 $\pm$ 1.76	2.87 $\pm$ 1.75	
Lean mass (kg)				
Treatment group	43.3 $\pm$ 0.6	4.29 $\pm$ 0.61	4.17 $\pm$ 0.61	0.13
Control	43.4 $\pm$ 0.6	2.61 $\pm$ 0.65	2.82 $\pm$ 0.64	
Intraabdominal fat (cm <sup>2</sup> )				
Treatment group	71.82 $\pm$ 4.43	-2.99 $\pm$ 5.04	7.05 $\pm$ 5.07	0.05
Control	67.38 $\pm$ 4.57	2.95 $\pm$ 5.38	21.36 $\pm$ 5.34	
Subcutaneous abdominal fat (cm <sup>2</sup> )				
Treatment group	269.24 $\pm$ 9.20	-1.94 $\pm$ 2.04	0.97 $\pm$ 2.05	0.08
Control	252.34 $\pm$ 9.49	-0.88 $\pm$ 2.17	6.12 $\pm$ 2.16	

<sup>1</sup>  $P$  for test between group differences during 2 y were derived from repeated-measures ANCOVA adjusted for ethnicity and physical activity at baseline and for kilocalorie intake and marital status at baseline and 2 y.

<sup>2</sup>  $n = 82, 71,$  and  $70$  at baseline, year 1, and year 2, respectively.

<sup>3</sup> Adjusted  $\bar{x} \pm SE$  (all such values).

<sup>4</sup>  $n = 82, 67,$  and  $63$  at baseline, year 1, and year 2, respectively.

reduced intraabdominal fat (29, 32) after 4 mo of strength training. The investigators of the null study speculated that strength training might only affect intraabdominal fat in participants who have greater fat to lose (eg, older or overweight adults) (30). The present results indicate that strength training can affect intraabdominal fat in midlife overweight and obese women.

The choice to provide brochures only to the control group was intentional, to allow for a group that would be provided with the current standard public health intervention for physical activity. Although this choice provides useful information about the efficacy of such interventions, it is acknowledged that this creates an imbalance in contact with study personnel across the treatment compared with control groups. Although this study did experience differential loss to follow-up across treatment status, between-group comparisons for demographics and the 2 most important potential confounders (diet and physical activity) did not show differences at any measurement time point. The measurement of physical activity by objective monitoring avoided the potential for desirability bias from self-report that may occur in intervention studies. No such objective monitoring of dietary changes was possible. Further, food-frequency questionnaires such as the DHQ may not be sensitive enough to capture changes in dietary pattern. The possibility that significant changes in dietary intake influenced the body composition results reported cannot be ruled out. The validity of self-completed exercise logs to determine strength-training adherence is supported by greater strength gains during 1 and 2 y in the treatment group than in the comparison group. Strengths of the SHE study include the large sample size, the ethnic diversity of the participants (nearly 40% nonwhite), and the long intervention period. To our knowledge, this study represents the longest exercise intervention to examine effects on intraabdominal fat with the use of imaging technology.

In summary, US women aged 25–44 y gain 0.5–1 kg annually, on average. Most of this weight gain can be assumed to be fat (4, 33), including abdominal fat (34), which has particularly adverse metabolic effects (6, 28, 35, 36). This study observed that twice-weekly strength training prevents increases in total percentage body fat and attenuates intraabdominal fat increases in overweight and obese premenopausal women. Because these women are already overweight or obese, weight-loss efforts would be desirable. That said, obesity prevention interventions such as twice-weekly strength training are vital to our efforts to slow the increase in population prevalence of obesity and weight gain among overweight and obese women. These findings are particularly relevant to an aging population and the avoidance of the development of sarcopenic obesity in the elderly.

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