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Physical Activity and Changes in Weight and Waist Circumference in Midlife Women: Findings from the Study of Women's Health Across the Nation

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Controversy exists regarding the extent to which age, menopausal status, and/or lifestyle behaviors account for the increased weight, fat mass, and central adiposity experienced by midlife women. To address this question, the authors longitudinally examined the relations of aging, menopausal status, and physical activity to weight and waist circumference in 3,064 racially/ethnically diverse women aged 42–52 years at baseline who were participating in the Study of Women's Health Across the Nation (SWAN), an observational study of the menopausal transition. Over 3 years of follow-up (1996–1997 to 1999–2000), mean weight increased by 2.1 kg (standard deviation (SD), 4.8) or 3.0% (SD, 6.5) and mean waist circumference increased by 2.2 cm (SD, 5.4) or 2.8% (SD, 6.3). Change in menopausal status was not associated with weight gain or significantly associated with increases in waist circumference. A one-unit increase in reported level of sports/exercise (on a scale of 1–5) was longitudinally related to decreases of 0.32 kg in weight ($p < 0.0001$) and 0.10 cm in waist circumference (not significant). Similar inverse relations were observed for daily routine physical activity (biking and walking for transportation and less television viewing). These findings suggest that, although midlife women tend to experience increases in weight and waist circumference over time, maintaining or increasing participation in regular physical activity contributes to prevention or attenuation of those gains.

adipose tissue; body constitution; body weight changes; exercise; menopause; physical fitness; prospective studies; weight gain

Abbreviations: CI, confidence interval; SD, standard deviation; SWAN, Study of Women's Health Across the Nation.

During the transition from premenopause to postmenopause, many women experience loss of lean mass (1) and gains in weight (2, 3), fat mass (4), and central fat deposition (5). However, controversy exists regarding the degree to which the increases in total fat and central fat over the course of the menopausal transition are the result of menopause itself or a consequence of chronologic aging. Although some cross-sectional studies (6, 7) have found postmenopausal women to be heavier than premenopausal women, most have not observed menopause-related differences in weight independently of age (1, 8–11). Longitudinal data from the Healthy Women's Study (2) and from a study in Scotland (3), both of which followed initially premenopausal women over time, found that women who remained premenopausal

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gained the same amount of weight as those who became postmenopausal. The evidence regarding menopause-related changes in body composition (increased fat mass, decreased lean mass) is more mixed; some studies support an association (1, 6, 11–14) and others do not (8, 9). There is general agreement that menopause is associated with increased central adiposity, particularly visceral fat (12, 15, 16), though most of this evidence has come from cross-sectional studies with relatively small samples (7, 8, 12) and not all of the evidence supports that conclusion (1, 6, 17).

Regardless of whether midlife changes in body composition and fat distribution are hormone- and/or age-related, the relevant question from a public health perspective is whether there are modifiable factors that can prevent or minimize these changes. A large body of cross-sectional evidence indicates that physical activity is associated with less body fat, more lean mass, and less central adiposity in both premenopausal (18–20) and postmenopausal (21, 22) women, but only limited longitudinal data exist related to changes in physical activity and body size and composition, especially during the menopausal transition.

The Study of Women's Health Across the Nation (SWAN), a multisite, prospective, community-based observational study of the natural menopause in a multiethnic cohort of initially premenopausal or early perimenopausal women, offers researchers a unique opportunity to understand factors that influence weight and fat gain and fat redistribution in midlife. The purpose of the current investigation was to evaluate 3-year changes in weight and waist circumference in SWAN and to examine the contributions of aging and change in menopausal status and physical activity to those changes.

MATERIALS AND METHODS

Study sample

The sample was drawn from the 3,302 women who constitute the SWAN cohort. Recruitment procedures and the study design used for SWAN have been described elsewhere (23). Briefly, in 1996–1997, women aged 40–55 years were screened from defined sampling frames at seven clinical sites throughout the United States: Boston, Massachusetts; Chicago, Illinois; Detroit, Michigan; Los Angeles, California; Newark, New Jersey; Oakland, California; and Pittsburgh, Pennsylvania. If women were eligible, they were invited to participate in a longitudinal study of natural menopause. To be eligible, women had to be between 42 and 52 years of age, to report having had a menstrual period and no use of hormone therapy in the 3 months prior to recruitment, and to identify their primary race/ethnicity as African-American (Boston, Chicago, Detroit, and Pittsburgh), Japanese (Los Angeles), Hispanic (Newark), Chinese (Oakland), or White (all sites). The cohort participated in a baseline clinical examination and continues to participate in annual follow-up examinations. Retention for the third follow-up visit (year 3), the last data point with data available for this analysis, was 82.0 percent. All participants gave informed consent, and all study procedures were reviewed and approved by the institutional review boards of the participating institutions.

Excluded from the present analysis were women who had missing baseline measurements of both weight and waist circumference ($n = 81$) or missing data on chronic conditions that could affect change in body mass or composition ($n = 1$). Women with extreme values for change in weight or waist circumference, defined as more than 25 kg or more than 25 cm, respectively, on the basis of graphic inspection of the data points, were also excluded ($n = 28$). Additional exclusions included women who reported pregnancy or breast-feeding ($n = 18$) or cancer other than skin cancer ($n = 110$). The remaining 3,064 women constituted the sample for the current analysis.

Body size measurements

The outcomes of interest were body fat and fat distribution. Since body composition was not measured at all SWAN sites, weight was used as a measure of body fat. Body mass index (weight (kg)/(height (m)^2), which correlates highly with percentage of body fat measured by techniques such as dual-energy x-ray absorptiometry or bioelectrical impedance (24), is a better measure of body fatness than weight alone. However, body mass index is a ratio, and interpreting the results of regression analyses that use change in a ratio as the outcome variable is inherently problematic (25). To avoid these problems, we defined the outcome variable as change in weight, since weight also correlates well with more precise measures of body fat (25), and in this study change in weight was highly correlated with change in body mass index ($r = 0.95$). Weight was measured to the nearest 0.1 kg at each annual examination on either a balance beam or a digital scale (varying by clinical site but consistent over time within site) while participants stood in stocking feet and light clothing. Waist circumference, considered a valid marker of central adiposity (26, 27), was measured annually to the nearest 0.1 cm with a measuring tape placed horizontally around the participant at the narrowest part of the torso.

Changes in weight and waist circumference were calculated, in absolute terms, as the difference between year 3 and baseline and, in relative terms, as a percentage of the baseline value ((year 3 minus baseline)/baseline). Substantial gains in weight and waist circumference were defined categorically as values greater than the 75th percentile of percentage change (more than a 6.6 percent increase in weight and more than a 6.2 percent increase in waist circumference), while weight and waist stability were defined as a percentage change falling between the 10th percentile (–4.7 percent and –4.3 percent for weight and waist circumference, respectively) and the 75th percentile. A percentage change below the 10th percentile was considered a substantial decrease in weight or waist circumference.

Exposure variables

Age, menopausal status, and physical activity were the major independent variables. Baseline age was calculated as the difference between the date of baseline examination and the date of birth. Follow-up time in years was used to represent aging and was calculated for each woman as the difference between the dates of each consecutive pair of examinations. Menopausal status was defined at each visit on the basis of self-reported bleeding patterns, using the following algorithm—1) premenopause: a menstrual period within the past 3 months with no change in regularity; 2) early perimenopause: a menstrual period within the past 3 months but with a self-reported change in cycles; 3) late perimenopause: no menstrual bleeding for at least 3 months but no more than 12 months; 4) postmenopause: no menstrual bleeding for at least 12 months; 5) surgical menopause: bilateral oophorectomy; and 6) undetermined: use of hormone therapy or hysterectomy without bilateral oophorectomy prior to 12 months of amenorrhea. Analytically, categories of menopausal status were considered relative to premenopause.

Physical activity was assessed at baseline and at year 3 using an adaptation of the Kaiser Physical Activity Survey (28). This survey is a self-administered questionnaire with established test-retest reliability and validity against activity records, accelerometer recordings, and maximal oxygen consumption among White women (29) and concurrent validity among racial/ethnic minority women in terms of body mass index and socioeconomic factors (28). Originally adapted from the Baecke questionnaire (30), the version of the Kaiser Physical Activity Survey used in SWAN consists of 38 questions with primarily Likert-scale responses about physical activity in various domains, including sports/exercise, household/caregiving, and daily routine (defined as walking or biking for transportation and hours of television viewing, which are reverse-scored). We derived domain-specific activity indices ranging in value from 1 to 5 (5 indicating the highest level of activity) by averaging the ordinal responses to questions in each domain. Change in domain-specific activity was defined continuously as the difference between values at year 3 and baseline and categorically as a three-level variable that corresponded to a decrease, no change, and an increase on the basis of the distribution (approximately, the 25th percentile, interquartile range, and 75th percentile for change in sports/exercise and tertiles for change in daily routine and household/caregiving activity).

Covariates

Baseline body mass index was used to adjust analyses of weight and waist change for initial level of body fat. Other covariates included self-reported race/ethnicity (African-American, Chinese, Hispanic, Japanese, or White), smoking status (never smoker, current smoker, former smoker), and perceived overall health (excellent/very good, good, fair/poor). A health status variable (chronic condition, no chronic condition) was created from self-reported information on the presence of chronic medical conditions or use of medications that might affect changes in body weight and fat distribution. This included diabetes mellitus, heart conditions, and stroke and the use of lipid-lowering drugs, antihypertensive agents, corticosteroids, anticoagulants, or antidepressants. Also included was an abnormal thyroid-stimulating hormone value (>5 mIU/ml or <0.5 mIU/ml), assessed using the Bayer ACS:180 thyroid-stimulating hormone assay (Bayer Diagnostics, Tarrytown, New York).

Data analyses

Baseline values for the dependent and independent variables and 3-year changes in these variables were proportions or mean values and standard deviations. Baseline values for the physical activity indices, for which data were highly skewed, were medians and interquartile ranges. We used paired *t* tests to evaluate whether within-woman change in the continuous variables (weight, waist circumference, and physical activity), all of which were normally distributed, differed significantly from zero.

Our main approach to multivariable analysis was to examine weight and waist circumference as continuous variables over time, using repeated-measures linear regression (PROC MIXED procedure in SAS; SAS Institute, Inc., Cary, North Carolina) to account for the correlation of within-woman repeated observations. Repeated measurements of weight or waist circumference from baseline through the third follow-up were modeled as a function of baseline age, race/ethnicity, and the repeated measures of follow-up time (aging), menopausal status, physical activity (measured only at baseline and at year 3), and other factors. The degree to which the associations between weight or waist circumference and physical activity were attributable to between-women differences in activity (an essentially cross-sectional effect) or within-woman changes (a longitudinal effect) was evaluated by separating each domain-specific physical activity index into two orthogonal variables: the within-woman mean value for the baseline and year 3 activity index and the within-woman difference between that mean value and the baseline or year 3 value (a repeated measure). To allow for estimation of the association of risk factors with waist circumference independently of weight, we included weight as a covariate in the model that used waist circumference as the outcome variable.

In addition, analysis of covariance provided estimates of the mean within-woman weight and waist change associated with categorical change in domain-specific physical activity, adjusted for covariates. Finally, we used logistic regression analysis to evaluate factors related to risk of substantial weight or waist gain relative to women whose weight or waist circumference remained essentially stable. Those with a substantial decrease in weight or waist circumference were excluded from this analysis.

For each of these approaches, we constructed separate models for each outcome (weight or waist circumference). Initially, we used separate models for each of the domains of physical activity, but the domain-specific indices were, at most, modestly correlated, and the final models included all activity variables. We selected potential confounders on the basis of the literature and a priori hypotheses. We included site to account for differences in sampling frames. We examined potential interactions between physical activity and baseline body mass index and physical activity and race/ethnicity by stratification and by entering appropriate cross-product terms into the models, but we observed no meaningful effect modification. We considered the effect of

TABLE 1. Baseline characteristics and changes in body size, menopausal status, and physical activity over a 3-year period (*n* = 3,064), Study of Women's Health Across the Nation, 1996–1997 to 1999–2000*

Characteristic	No.	%	Mean or median	SD† or IQR†
Baseline				
Mean age (years)			45.9	2.7
Race/ethnicity				
African-American	856	27.9		
Chinese	239	7.8		
Hispanic	267	8.7		
Japanese	267	8.7		
White	1,435	46.8		
Menopausal status				
Premenopausal	1,610	53.9		
Early perimenopausal	1,375	46.1		
Mean weight (kg)			74.2	19.7
Mean waist circumference (cm)			85.9	15.4
Mean body mass index‡			29.0	6.9
Median level of physical activity§				
Sports/exercise			2.5	1.8–3.5
Daily routine			2.5	2.0–3.0
Household/caregiving			2.6	2.2–3.4
3-year change (from baseline to year 3)				
Weight				
Mean absolute change (kg)			2.06¶	4.8
Mean relative change (%)			3.01¶	6.5
Waist circumference				
Mean absolute change (cm)			2.24¶	5.4
Mean relative change (%)			2.77¶	6.3
Change in menopausal status				
Stayed premenopausal	284	11.7		
Stayed early perimenopausal	539	22.3		
Became early perimenopausal	722	29.8		
Became late perimenopausal	213	8.8		
Became naturally postmenopausal	312	12.9		
Hormone therapy or surgical menopause	272	11.2		
Mean change in physical activity				
Sports/exercise			0.08¶	0.9
Daily routine			–0.01	0.7
Household/caregiving			–0.14¶	0.8
Categorical change#				
Sports/exercise				
Decrease	403	17.4		
No change	1,361	58.9		
Increase	547	23.7		
Daily routine				
Decrease	797	33.3		
No change	819	34.3		
Increase	775	32.4		
Household/caregiving				
Decrease	763	31.8		
No change	1,146	47.8		
Increase	488	20.4		

* Sample sizes differ for specific variables because of missing values and nonparticipation in the third follow-up.
† SD, standard deviation; IQR, interquartile range.
‡ Weight (kg)/height (m)^2.
§ Measured on a scale of 1–5 (see text for details).
¶ In a paired *t* test for mean within-woman change significantly different from zero, $p < 0.0001$.
# The definitions of decrease, no change, and increase were based on the distributions of change, as follows: for sports/exercise, <–0.5, –0.5 to 0.5, and >0.5; for daily routine, <0, 0, and >0; and for household/caregiving, <–0.4, –0.4 to 0.4, and >0.4.

extreme data points by constructing models that excluded the upper fifth percentile of the distribution. Since the results did not vary regardless of whether these points were included, data from all observations are reported.

RESULTS

As table 1 shows, mean weight increased over the 3-year period by 2.1 kg (standard deviation (SD), 4.8) or 3.0 percent (SD, 6.5) and mean waist circumference increased by 2.2 cm (SD, 5.4) or 2.8 percent (SD, 6.3). One third of the women in the cohort had not transitioned from their baseline menopausal status (premenopausal or early perimenopausal) by year 3, and only 13 percent had become naturally postmenopausal. There were small but statistically significant mean changes in sports/exercise and household/caregiving, but there was no mean change in daily routine activity.

Longitudinal analyses of weight and waist circumference

The longitudinal associations of time (aging), menopausal status, physical activity (as a continuous variable), and other factors with weight and waist circumference are presented in

TABLE 2. Results from longitudinal analysis of weight and waist circumference over a 3-year period as a function of baseline age, time, menopausal status, physical activity, and other factors, Study of Women's Health Across the Nation, 1996–1997 to 1999–2000*

	Weight (kg)			Waist circumference (cm)		
	β	SE†	*p* value	β	SE	*p* value
Baseline age (1 year)	–0.03	0.11	0.78	0.18	0.04	<0.0001
Follow-up time (1 year)	0.65	0.04	<0.0001	0.21	0.03	<0.0001
Menopausal status						
Premenopausal‡						
Early perimenopausal	–0.01	0.11	0.95	–0.04	0.11	0.73
Late perimenopausal	–0.08	0.21	0.69	0.03	0.20	0.88
Postmenopausal	0.07	0.25	0.79	0.38	0.23	0.10
Undetermined	0.04	0.19	0.83	0.31	0.18	0.08
Mean level of physical activity§,¶ (one unit)						
Sports/exercise	–2.76	0.36	<0.0001	–0.58	0.12	<0.0001
Daily routine	–3.31	0.46	<0.0001	–0.92	0.15	<0.0001
Household/caregiving	0.43	0.41	0.30	0.17	0.13	0.20
Change in physical activity# (one unit)						
Sports/exercise	–0.32	0.08	<0.0001	–0.10	0.07	0.18
Daily routine	–0.21	0.10	0.03	–0.14	0.09	0.14
Household/caregiving	–0.15	0.09	0.10	0.01	0.08	0.88
Race/ethnicity						
African-American	5.04	0.82	<0.0001	–0.66	0.27	0.01
Chinese	–17.88	1.61	<0.0001	2.63	0.53	<0.0001
Hispanic	–3.30	1.82	0.07	2.79	0.61	<0.0001
Japanese	–11.55	1.55	<0.0001	1.93	0.51	0.0001
White‡						
Weight** (kg)				0.71	0.01	<0.0001
Perceived health						
Excellent/very good‡						
Good	0.56	0.16	<0.0001	0.26	0.10	0.0006
Fair/poor	0.79	0.04	<0.0001	0.54	0.15	0.0005
Health status						
Chronic conditions	6.52	0.62	<0.0001	1.27	0.21	<0.0001
No chronic conditions‡						
Smoking status						
Never smoker‡						
Former smoker	0.30	0.53	0.57	0.46	0.22	0.03
Current smoker	–1.52	0.52	0.004	0.99	0.23	<0.0001

* All results were adjusted for the other variables and for study site.
† SE, standard error.
‡ Reference category.
§ Measured on a scale of 1–5 (see text for details).
¶ Woman-specific mean of baseline and year 3 domain-specific activity scores.
\# Woman-specific mean minus baseline and mean minus year 3 domain-specific activity scores.
** Not included in the models that used weight as the outcome.

table 2. Weight increased steadily with each year of follow-up but did not vary by baseline age or differences in menopausal status. Both mean level (between-women differences) of sports/exercise and daily routine activity and within-woman changes in those domains of activity significantly influenced weight over time. As estimated by the beta coef-

ficient, a one-unit difference in the mean level of sports/exercise was inversely associated with a 2.76-kg (standard error, 0.36) difference between women in weight. Similarly, a one-unit within-woman increase in that domain over time (beta coefficient for change in activity) was associated with a 0.32-kg (standard error, 0.08) decrease in weight. The influence of the between-women variability in daily routine activity was of even greater magnitude ($\beta = -3.31$ (standard error, 0.46); $p < 0.0001$), but the magnitude of the within-woman variability was slightly lower ($\beta = -0.21$ (standard error, 0.10); $p = 0.03$). In contrast, mean household/caregiving activity had no relation with weight, although an increase in activity in this domain was marginally associated with a decrease in weight ($p = 0.10$). Racial/ethnic differences in weight, which were apparent at baseline (the mean ranged from a high of 84.2 kg (SD, 20.2) in African Americans to 58.2 kg (SD, 10.8) and 56.1 kg (SD, 8.8) in the Chinese and Japanese, respectively), persisted over time, with the African-American women being heavier than White women and the Chinese, Hispanic, and Japanese women being lighter than White women. Weight was also directly related to having a chronic medical condition and poorer perceived health and inversely related to current cigarette smoking. Exclusion of current smokers did not alter these relations (data not shown).

Waist circumference, which increased as weight increased, also increased independently with older baseline age and with time. Menopausal status was not significantly related to waist circumference, but waist circumference tended to be higher in women who became postmenopausal or whose status was undetermined. Sports/exercise activity and daily routine activity were inversely related; the variability in waist circumference attributable to these two domains of activity was due primarily to differences in mean level (between-women differences) and less to change in activity (within-woman variability) ($p = 0.18$ and $p = 0.14$ for change in sports/exercise and daily routine, respectively). Unlike the relations between race/ethnicity and weight, waist circumference, after adjustment for weight, was slightly lower in the African Americans than in Whites and significantly higher in Chinese, Hispanics, and Japanese. In addition, current cigarette smoking, after adjustment for weight, was associated with greater waist circumference, as were poorer perceived health and having a chronic medical condition.

Change in physical activity and within-woman change in weight and waist circumference

Figures 1, 2, 3, and 4 illustrate the mean within-woman change in weight and waist circumference for different categories of change in sports/exercise and daily routine activity, adjusted for covariates, including baseline activity. In these domains of activity, the groups that decreased their level of activity gained the most weight (adjusted least-squares mean = 2.7 kg (95 percent confidence interval (CI): 2.2, 3.3) for sports/exercise and 2.4 kg (95 percent CI: 1.9, 2.8) for daily routine activity), and those that increased their activity gained the least (least-squares mean = 1.0 kg (95 percent CI: 0.5, 1.5) for sports/exercise and 1.4 kg (95 percent CI: 0.9, 1.8) for daily routine). Similar group differences in mean waist gain were also observed. Neither weight change nor change in waist circumference varied by change in household/caregiving activity (data not shown).

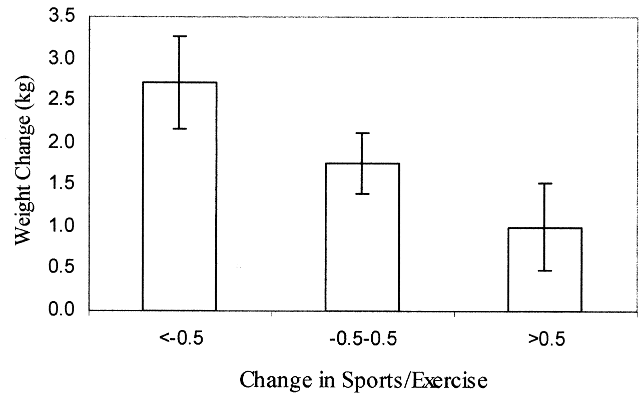

FIGURE 1. Mean within-woman weight change between baseline (1996–1997) and year 3 (1999–2000) according to change in the level of sports/exercise (on a scale of 1–5), Study of Women's Health Across the Nation. Results were adjusted for baseline age, baseline level of sports/exercise, race/ethnicity, the presence of chronic conditions, and study site. For the *F* statistic, $p < 0.0001$; all pairwise comparisons showed a significant difference at $p < 0.01$. Bars, 95% confidence interval.

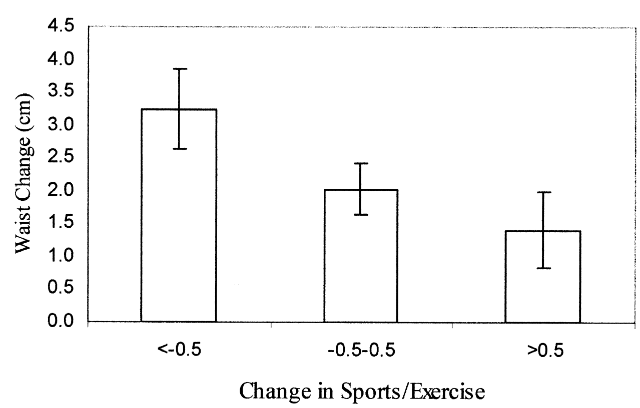

FIGURE 2. Mean within-woman change in waist circumference between baseline (1996–1997) and year 3 (1999–2000) according to change in the level of sports/exercise (on a scale of 1–5), Study of Women's Health Across the Nation. Results were adjusted for baseline age, baseline level of sports/exercise, race/ethnicity, the presence of chronic conditions, and study site. For the *F* statistic, $p < 0.0001$; all pairwise comparisons showed a significant difference at $p < 0.05$. Bars, 95% confidence interval.

Factors associated with risk of substantial gain in weight and waist circumference

The results of the multivariable logistic regression analyses are summarized in table 3. In general, these results are consistent with those of the longitudinal analysis. Risk of

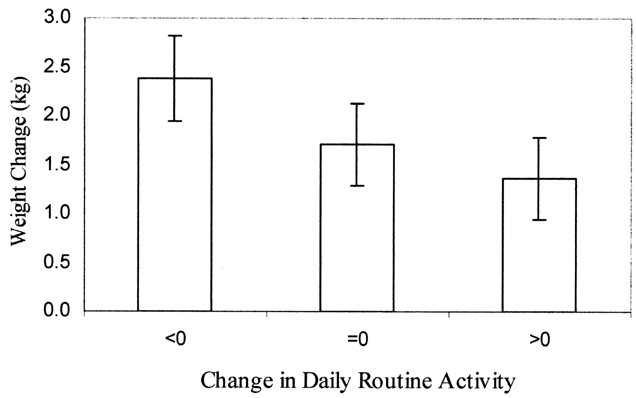

FIGURE 3. Mean within-woman weight change between baseline (1996–1997) and year 3 (1999–2000) according to change in the level of daily routine physical activity (on a scale of 1–5), Study of Women's Health Across the Nation. Results were adjusted for baseline age, baseline level of daily routine activity, race/ethnicity, the presence of chronic conditions, and study site. For the *F* statistic, $p < 0.001$; the group with a decrease in activity (change <0) was significantly different from the other two groups at $p < 0.01$. Bars, 95% confidence interval.

substantial weight gain was not associated with baseline age, baseline menopausal status, or change in menopausal status. Although baseline sports/exercise was not significantly associated with risk, change in that domain of activity was inversely associated (odds ratio = 0.77, 95 percent CI: 0.66, 0.89), as were both baseline level of daily routine activity and change in daily routine activity. Of the factors associated with substantial gain in waist circumference, the most notable was the 32 percent increase in risk associated with a 1-kg increase in weight. Increases over time in the sports/exercise and daily routine indices tended to be associated with lower risk, but only the relation with sports/exercise was statistically significant. Baseline smoking status was not significantly associated with either substantial weight gain or substantial gain in waist circumference and was not included in the model. Although smoking cessation was significantly associated with risk of substantial weight gain, only 54 women gave up smoking during follow-up, and inclusion of this variable did not alter the other relations (data not shown).

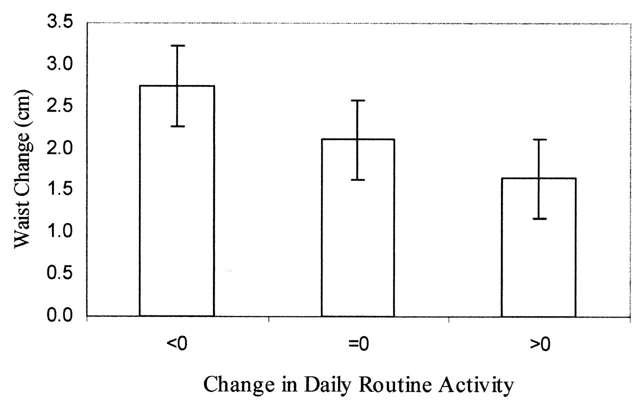

FIGURE 4. Mean within-woman change in waist circumference between baseline (1996–1997) and year 3 (1999–2000) according to change in the level of daily routine physical activity (on a scale of 1–5), Study of Women's Health Across the Nation. Results were adjusted for baseline age, baseline level of daily routine activity, race/ethnicity, the presence of chronic conditions, and study site. For the *F* statistic, $p < 0.002$; the group with a decrease in activity (change <0) was significantly different from the other two groups at $p < 0.05$. Bars, 95% confidence interval.

DISCUSSION

In this study of a multiethnic cohort of midlife women, significant increases in mean weight and waist circumference occurred over the 3-year follow-up period. Time was a risk factor for weight gain, but change in menopausal status was not, whether the outcome was considered continuously, as a repeated measure over time, or categorically, in terms of a substantial gain. Time was also a risk factor for increases in waist circumference, as was baseline age. Although change in menopausal status was not significantly associated with change in waist circumference, women who became postmenopausal or who began hormone therapy tended to have larger waists than women who remained premenopausal or early perimenopausal. In the longitudinal analysis, higher levels of sports/exercise and daily routine activity were independently associated with lower weight and waist circumference. Greater levels of participation in both of these domains of activity and increases in participation over time also tended to be associated with lower risk of substantial weight gain. Furthermore, when within-woman changes in weight and waist circumference were examined in relation to categorical change in activity, women who increased their activity had the least amount of gain, while those who decreased their activity had the most.

The finding that weight increased steadily over a 3-year period is consistent with the well-established observation that weight tends to increase with age in young and middle-aged adults (31, 32). It is notable that the mean within-woman weight gain of 2.1 kg in the SWAN cohort is only slightly lower than the 2.4-kg weight gain seen in the Healthy Women's Study, a cohort study of primarily White women, over a similar period of time (2), although it is greater than the increase of 2.9–4.5 kg observed over a 6-year follow-up period in Scottish women (3). These findings imply that women in their forties and early fifties may, on average, expect to gain approximately 1.5 pounds (0.7 kg) per year during their middle years, regardless of initial age, initial body size, or race/ethnicity. On the other hand, there was a large degree of individual variability in the tendency to gain weight over time, and almost one fourth of the SWAN women lost at least 2 percent of their initial body weight over the 3-year follow-up period.

In this study, differences in physical activity in the domains of both sports/exercise and daily routine contributed to the variability in weight over time. The findings from the longitudinal analysis demonstrated that variability in weight over time was attributable not only to variability in activity level between women but also to within-woman

TABLE 3. Odds ratio for a substantial gain in weight or waist circumference over a 3-year period, Study of Women's Health Across the Nation, 1996–1997 to 1999–2000*,†

	Weight gain		Waist gain	
	OR‡	95% CI‡	OR	95% CI
Baseline age (years)	0.98	0.94, 1.03	1.03	0.96, 1.05
Baseline menopausal status				
Premenopausal§				
Early perimenopausal	1.26	0.96, 1.64	1.39	1.04, 1.86
Change in menopausal status				
No change§				
From premenopausal to early perimenopausal	0.93	0.90, 1.71	0.97	0.68, 1.38
From pre-/early perimenopausal to hormone use	1.07	0.74, 1.54	0.93	0.78, 1.71
From pre-/early perimenopausal to late peri-/postmenopausal	1.24	0.93, 1.67	1.04	0.75, 1.44
Baseline level of physical activity¶ (one unit)				
Sports/exercise	0.94	0.84, 1.08	0.94	0.82, 1.09
Daily routine	0.85	0.72, 1.01	1.12	0.93, 1.36
Household/caregiving	0.93	0.80, 1.08	1.06	0.90, 1.25
Change in physical activity# (one unit)				
Sports/exercise	0.77	0.66, 0.89	0.84	0.72, 0.98
Daily routine	0.79	0.66, 0.94	0.91	0.75, 1.11
Household/caregiving	0.92	0.78, 1.08	1.25	1.04, 1.49
Baseline body mass index** (one unit)	0.96	0.94, 0.98	0.98	0.96, 1.00
Change in weight (year 3 minus baseline)†† (kg)			1.32	1.28, 1.37
Race/ethnicity				
African-American	1.45	1.09, 1.94	1.12	0.82, 1.53
Chinese	0.58	0.33, 1.03	0.83	0.46, 1.47
Hispanic	0.69	0.30, 1.58	2.90	1.01, 8.35
Japanese	0.43	0.27, 0.68	0.77	0.43, 1.36
White§				
Health status				
Chronic condition	1.36	1.09, 1.70	1.11	0.87, 1.42
No chronic condition§				

* Substantial weight gain, defined as more than a 6.6% increase over initial body weight (75th percentile of the distribution), was compared with weight stability, defined as a change between –4.7% (10th percentile) and 6.6%; substantial waist gain, defined as more than a 6.2% increase over initial waist circumference (75th percentile of the distribution), was compared with waist stability, defined as a change between –4.3% (10th percentile) and 6.2%. Women with a change in weight or waist circumference below the 10th percentile were excluded from this analysis.

† All results were adjusted for the other variables and for study site.

‡ OR, odds ratio; CI, confidence interval.

§ Reference category.

¶ Measured on a scale of 1–5 (see text for details).

\# Change in domain-specific activity was defined as year 3 value minus baseline value.

** Weight (kg)/height (m)^2.

†† Not included in the weight gain model.

variability. This suggests that, regardless of the starting level, any decrease in activity level in midlife women is associated with higher weight over time, while increases in activity are associated with lower weight. The fact that the least amount of within-woman weight change was observed among the women who increased their sports/exercise or daily routine activity also underscores the critical role of regular physical activity in weight maintenance. Similar associations between increased physical activity and attenuated weight gain have been observed in several other cohort studies, such as the Coronary Artery Risk Development in Young Adults (CARDIA) Study (33), the First National Health and Nutrition Examination Survey (NHANES I) Epidemiologic Follow-up Study (34), and the Health Professionals Follow-up Study (35). Even more relevant are the similar findings in the Healthy Women's Study (36) and the osteoporosis screening study from Aberdeen, Scotland (3)—perhaps the only two other studies that have addressed this question directly in women undergoing menopause.

The absence of any relation between household/caregiving activity and weight change suggests that, although women may spend a great deal of time in activities in this domain (37), the intensity of the activities is generally low, resulting in minimal energy expenditure and thus having little impact on weight-change patterns.

Within-woman changes in sports/exercise and daily routine activity appeared to have somewhat less influence on waist circumference independently of the influence of weight. Although the associations pointed in the inverse direction expected in both the longitudinal analysis, which modeled waist circumference over time, and the logistic regression analysis, which modeled likelihood of substantial waist gain, they did not achieve statistical significance. This implies that physical activity may contribute more to preventing increases in the overall amount of fat than to preventing redistribution of that fat.

Even though the longitudinal associations between menopausal status and waist circumference observed in SWAN were not statistically significant, they were suggestive of the findings of a number of cross-sectional studies (7, 12–14) that have reported greater central adiposity in postmenopausal women than in premenopausal women. The relatively short follow-up period in SWAN and the relatively small number of transitions to postmenopausal status may account for the lack of a stronger association. However, other studies have failed to find more central adiposity in postmenopausal women (9, 17), and those that have generally have not taken into account changes in weight or physical activity. At this point, the question of whether or not there is a menopause-related increase in central adiposity that is independent of age-related increases in weight remains unresolved.

Adjustment for weight also resulted in longitudinal racial/ethnic differences in waist circumference that contrasted with those observed for weight. Specifically, African-American women, despite greater weight relative to Whites, did not have greater changes in waist circumference, while the other three racial/ethnic groups, all of whom were lighter than the White women, did. These findings may be the result of a proportionally greater increase in waist circumference for any given weight change in smaller women.

Several limitations of the present analysis deserve mention. Most notable is the absence of information on change in dietary intake. Although diet was assessed in SWAN at baseline with an adaptation of the Block food frequency questionnaire (38), it was not reassessed during the first 3 years of follow-up. As a result, the effect of dietary change on weight and waist gain could not be evaluated. However, other studies that have examined the effects of change in diet and physical activity on weight or waist change have found both to be significant independent factors (3, 35). Furthermore, in at least one study, the variance in weight change attributable to change in physical activity was more than seven times that accounted for by dietary change (3). In the current study, the magnitude and consistency of the relations between physical activity and weight across a variety of analytical approaches suggest that confounding by diet is not a likely explanation for the findings.

Other limitations of the current analysis include a relatively short follow-up period and few transitions to postmenopausal status. Finally, the sensitivity of the Kaiser Physical Activity Survey in measuring change in activity is unknown, and some degree of the observed change may have been due to measurement error.

This study also had several notable strengths. The prospective design, which allowed for consideration of within-woman variability, is more informative than the cross-sectional design of the studies that comprise most of the literature on body composition and fat distribution in midlife women. In addition, our investigation of these issues in a multiethnic cohort is essentially unique. Finally, the detailed assessment of domain-specific physical activity revealed differences in the relations by domain that have important implications for health promotion efforts.

From a public health perspective, the strongest finding to emerge from this study is the extent to which physical activity, both in specific sports and exercise and as part of an active lifestyle (more active transportation and less television viewing), contributes to weight maintenance in midlife women. Not only do women who enter midlife with a higher level of physical activity and maintain that level weigh less to begin with and gain less weight over time, but women who increase their level of activity in midlife, regardless of where they start from, also gain less weight. The ongoing challenge for public health professionals is developing more effective strategies to promote and support adoption and maintenance of regular physical activity in midlife women.

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