PHYSICALLY ACTIVE LIFESTYLES have been consistently related to reduced mortality and morbidity from cardiovascular disease (CVD), diabetes, physical disability, and certain cancers.\(^1^\)\(^-^\)\(^4\) Although primarily observed in middle-aged male populations,\(^1^\)\(^-^\)\(^4\) these benefits have also been demonstrated among older men and women.\(^10^\)\(^-^\)\(^16^\) Additional studies have shown that persons who increase their physical activity or fitness levels over time reduce their risk of cardiovascular and all-cause mortality.\(^17^\)\(^-^\)\(^21^\) However, these studies of changes in physical activity have mostly examined middle-aged populations and men, and the single study that examined the relationship between changes in physical activity and mortality among older women did not find a reduced mortality risk among women who increased their physical activity levels.\(^21^\) Thus, it remains unclear whether adoption of a physically active lifestyle by previously sedentary older women—particularly those with chronic conditions such as CVD, diabetes, and physical frailty—leads to similar benefits. Since more than one third of older adults are sedentary\(^22^\) and most of them have 1 or more chronic conditions,\(^23^\) the effects of changes in physical activity on mortality for this segment of the population have important public health implications.

In the present study, we examined whether changes in physical activity levels were associated with reduced mortality among a large population of older community-dwelling women.

Context Physical activity has been related to reduced mortality, but it is not clear whether changes in physical activity affect mortality among older women.

Objective To examine the relationship of changes in physical activity and mortality among older women.

Design, Setting, and Participants Prospective cohort study conducted at 4 US research centers (Baltimore, Md; Portland, Ore; Minneapolis, Minn; and Mononga-hela Valley, Pa) among 9518 community-dwelling white women aged 65 years or older who were assessed at baseline (1986-1988), 7553 of whom were reassessed at a follow-up visit (1992-1994; median, 5.7 years later).

Main Outcome Measures Walking and other physical activities at baseline and follow-up; vital status, with cause of death confirmed by death certificates/discharge summaries, tracked for up to 12.5 years after baseline (up to 6.7 years after the follow-up visit).

Results Compared with continually sedentary women, those who increased physical activity levels between baseline and follow-up had lower mortality from all causes (hazard rate ratio [HRR], 0.52; 95% confidence interval [CI], 0.40-0.69), cardiovascular disease (HRR, 0.64; 95% CI, 0.42-0.97), and cancer (HRR, 0.49; 95% CI, 0.29-0.84), independent of age, smoking, body mass index, comorbid conditions, and baseline physical activity level. Associations between changes in physical activity and reduced mortality were similar in women with and without chronic diseases but tended to be weaker among women aged at least 75 years and among those with poor health status. Women who were physically active at both visits also had lower all-cause mortality (HRR, 0.68; 95% CI, 0.56-0.82) and cardiovascular mortality (HRR, 0.62; 95% CI, 0.44-0.88) than sedentary women.

Conclusion Increasing and maintaining physical activity levels could lengthen life for older women but appears to provide less benefit for women aged at least 75 years and those with poor health status.

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Women were recruited from population-based lists in 4 US communities: Baltimore, Md; Portland, Ore; Minneapolis, Minn; and Monongahela Valley, Pa. The SOF excluded women if they were institutionalized or unable to walk without the assistance of another person. African American women were excluded from the SOF because of their lower fracture incidence.

All participants attended a baseline visit between 1986 and 1988, when physical activity levels and other behavioral and health status variables were available for 9518 women (186 women [2%] were excluded because of missing data). Physical activity levels were reassessed among 7553 nondisabled women who attended a follow-up visit 4.0 to 7.7 years later (1992-1994; median, 5.7 years). This sample served as the basis for analysis of change in physical activity, among whom vital status was subsequently tracked for up to 6.7 years after the second visit (through 1998-1999). In addition, we examined the association between baseline physical activity and mortality on the entire sample from baseline over 12.5 years of follow-up.

Of the 1965 women who were not part of the follow-up physical activity analysis, the following reasons for exclusion/loss to follow-up were noted: 1050 (11%) had died before the end of the visit period; 203 (2%) refused or were unable to attend the visit; 365 (4%) were excluded because they reported much difficulty or inability to walk at baseline; and 347 (4%) had missing data at follow-up. Women who did not attend the follow-up visit tended to be older at baseline (74.1 vs 71.0 years among those with follow-up data) and had a higher prevalence of hypertension (46.4% vs 36.3%), diabetes (11.2% vs 6.0%), stroke (6.5% vs 2.1%), and smoking (13.1% vs 9.2%) than those who attended both visits.

Assessment of Physical Activity
Physical activity was assessed using a modified version of the Harvard Alumni Questionnaire.24 Women were asked about the number of city blocks or equivalent (12 blocks = 1 mile [1.6 km]) they walked each day for exercise or as part of their normal routine and about frequency and duration of other leisure activities (eg, dancing, gardening, aerobics, swimming) during the past year. Walking for exercise was attributed an intensity of 8.3 kcal/block (equivalent to 5 kcal/min) and nonexercise walking was attributed 5 kcal/block (equivalent to 3 kcal/min). Other low- and moderate-intensity activities were attributed 5 kcal/min and 7.5 kcal/min, respectively. A summary estimate of physical activity was calculated and expressed in kilocalories per week.20,27 For analyses of changes in physical activity levels, we excluded information about high-intensity activities (eg, racquetball, running, team sports) to make computation of physical activity consistent across visits, because this information was collected only at baseline and high-intensity activities were reported by only 300 women (4.0%).

Classification of Physical Activity
For analyses of the association between baseline physical activity and mortality, we categorized women by quintile of total physical activity at baseline. For analyses of changes in physical activity levels, we compared mortality risks among 4 groups: those sedentary at both baseline and follow-up, defined as being in the lowest 40% (<595 kcal/wk); those physically active at baseline and sedentary at follow-up (ie, moved from highest 60% to lowest 40%); those sedentary at baseline and active at follow-up (ie, moved from lowest 40% to highest 60%); and those physically active at both visits. We also examined the amount of absolute kilocalorie change in physical activity (rather than quintile shifts relative to other women, as in our main analysis). For these analyses, the quintile with the least physical activity change was the referent group (referred to as maintainers); women with decreases and increases in physical activity were divided evenly into categories.

Other Measurements
Smoking; history of physician-diagnosed medical conditions, including coronary heart disease (myocardial infarction, angina, or congestive heart failure), diabetes, cancer, chronic obstructive pulmonary disease, and stroke; and self-rated health status were assessed by interview. Hip fractures that occurred between the 2 study visits were ascertained by postcard or telephone follow-up every 4 months and confirmed by radiographic report. Hypertension was defined as treatment with diuretic medications or having a blood pressure greater than 160/90 mm Hg. Body weight and height were measured at clinic visits and used to compute body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters).

Mortality
The methods of determining deaths have been published.28 Participants were contacted every 4 months, with 99% follow-up. Causes of death were confirmed by death certificates, and, when available, hospital discharge summaries were obtained. The underlying cause of death was coded by a clinical epidemiologist using the International Classification of Diseases, Ninth Revision, Clinical Modification, and categorized as due to all causes, CVD (ICD-9-CM codes 401 to <405, 410 to <415, 425, 428, 429.2, 430 to <439, 440 to <445, and 798), and cancer (ICD-9-CM codes 140 to 239).

Statistical Analysis
Age-adjusted mortality rates were computed using direct adjustment to the SOF sample population. Cox proportional hazards regression was used to assess the association of baseline physical activity levels (quintiles) and changes in physical activity (shifts in quintiles and kilocalorie change) with mortality. These analyses controlled for age, smoking, BMI, stroke, diabetes, coronary heart disease, hypertension, cancer, chronic obstructive pulmonary disease, hip fracture, and baseline physical activity level (kilocalo-
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Table 1. Characteristics of Study Population at Follow-up Visit by Change in Physical Activity Between Baseline and Follow-up*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total (n = 7553)</th>
<th>Stayed Sedentary (n = 3134)</th>
<th>Became Active (n = 811)</th>
<th>Became Sedentary (n = 1410)</th>
<th>Stayed Active (n = 1813)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking, median (IQR), mile/wk</td>
<td>4.1 (1.9-9.3)</td>
<td>1.8 (0.6-2.9)</td>
<td>2.3 (1.2-4.1)</td>
<td>7.0 (2.9-11.7)</td>
<td>8.2 (4.1-14.0)</td>
</tr>
<tr>
<td>At baseline</td>
<td>4.7 (1.2-9.9)</td>
<td>1.2 (0.6-3.5)</td>
<td>8.2 (4.7-12.8)</td>
<td>1.8 (0.6-4.1)</td>
<td>9.3 (5.8-14.0)</td>
</tr>
<tr>
<td>Energy expenditure, median (IQR), kcal/wk</td>
<td>848 (300-1740)</td>
<td>175 (70-350)</td>
<td>325 (152-462)</td>
<td>1137 (831-1725)</td>
<td>1713 (1120-2691)</td>
</tr>
<tr>
<td>At baseline</td>
<td>667 (152-1470)</td>
<td>105 (35-300)</td>
<td>1084 (805-1609)</td>
<td>210 (70-406)</td>
<td>1533 (1006-2331)</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>76.9 (4.9)</td>
<td>78.1 (5.3)</td>
<td>75.9 (4.4)</td>
<td>77.7 (5.2)</td>
<td>75.9 (4.2)</td>
</tr>
<tr>
<td>Body mass index, mean (SD)†</td>
<td>26.3 (4.7)</td>
<td>27.2 (5.2)</td>
<td>26.3 (4.5)</td>
<td>26.6 (4.8)</td>
<td>25.6 (4.1)</td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td>441 (5.8)</td>
<td>166 (7.5)</td>
<td>50 (6.2)</td>
<td>95 (6.7)</td>
</tr>
<tr>
<td>Past</td>
<td>2517 (33.3)</td>
<td>690 (31.4)</td>
<td>303 (37.4)</td>
<td>474 (33.6)</td>
<td>1050 (33.5)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>3358 (44.5)</td>
<td>1057 (48.1)</td>
<td>345 (42.5)</td>
<td>684 (48.5)</td>
<td>1272 (40.6)</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>1413 (18.7)</td>
<td>506 (23.0)</td>
<td>132 (16.3)</td>
<td>319 (22.6)</td>
<td>456 (14.6)</td>
</tr>
<tr>
<td>Stroke</td>
<td>224 (3.0)</td>
<td>94 (4.3)</td>
<td>12 (1.5)</td>
<td>67 (4.8)</td>
<td>51 (1.6)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>465 (6.2)</td>
<td>193 (8.8)</td>
<td>48 (5.9)</td>
<td>88 (6.2)</td>
<td>136 (4.3)</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>775 (10.3)</td>
<td>283 (12.9)</td>
<td>68 (8.4)</td>
<td>161 (11.4)</td>
<td>263 (8.4)</td>
</tr>
<tr>
<td>Cancer</td>
<td>1606 (21.3)</td>
<td>448 (20.4)</td>
<td>162 (20.0)</td>
<td>300 (21.3)</td>
<td>696 (22.2)</td>
</tr>
<tr>
<td>Hip fracture</td>
<td>173 (2.3)</td>
<td>71 (3.2)</td>
<td>9 (1.1)</td>
<td>52 (3.7)</td>
<td>41 (1.3)</td>
</tr>
<tr>
<td>Self-rated health status, fair/poor</td>
<td>1480 (19.6)</td>
<td>648 (29.5)</td>
<td>104 (12.8)</td>
<td>352 (25.0)</td>
<td>376 (12.0)</td>
</tr>
</tbody>
</table>

Abbreviation: IQR, interquartile range.
*Data are presented as number (percentage) unless otherwise noted and are based on information collected at the follow-up visit, except for walking and energy expenditure data, collected at baseline. P < .001 in a test for heterogeneity across groups for all variables except past smoking (P = .02) and cancer (P = .32). Hip fracture rates represent cumulative incidence between baseline and follow-up.
†Body mass index is calculated as weight in kilograms divided by the square of height in meters.

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ities per week). Covariates were based on assessments from the follow-up visit rather than baseline for all variables except BMI, in which case the most recent measurement was used (82% of the sample had BMI values at the follow-up visit and 18% [n = 1337] had BMI measured at an interim visit). Although statistical assumptions underlying the proportional hazards regression were met, we present our primary analyses in three 2.2-year segments because we found a tendency for stronger effects during the early years of follow-up. To explore potential bias due to underlying illness, we also conducted analyses in which we excluded data from the first 2 years of follow-up and present findings for which we found notable differences.

We also estimated propensity scores, evaluated the balance of covariates across 5 strata defined by propensity scores, and evaluated our primary exposure groups (sedentary vs increasers), stratified by propensity score. Propensity score methods reduce the bias in comparing exposure groups in observational studies and are an alternative to traditional covariance analysis adjustments (eg, regression models). Analyses were conducted using SAS version 8.2 (SAS Institute Inc, Cary, NC).

RESULTS

Among 9518 participants followed for up to 12.5 years (median, 10.6 years) from baseline, there were 2218 deaths, with 826 due to CVD and 633 due to cancer. Among the 7553 women in the analysis of the effects of change in physical activity, there were 1029 deaths (386 due to CVD and 264 due to cancer) over 6.7 years (median, 5.1 years) after the follow-up visit.

Table 1 shows study population characteristics at the follow-up visit by change in physical activity. Median walking distance at follow-up was 1.2 mile/wk for women who reported being sedentary at both visits, 1.8 mile/wk for those who became sedentary between visits, 8.2 mile/wk for women who became active, and 9.3 mile/wk for those active at both points. Women who reported being sedentary at both visits tended to be older, have a higher BMI, and were more likely to be smokers and have comorbid conditions than women who became active or were active at both study visits. Women who were active at baseline but became sedentary were also older and more likely to have comorbid conditions than those who became active or remained active.

Baseline Physical Activity and Mortality

Higher levels of total physical activity and walking at baseline were associated with lower all-cause and CVD mortality rates, controlling for age, BMI, smoking, and comorbid conditions (Table 2). The magnitude of risk reduction associated with physical activity was greatest for CVD mortality; compared with the lowest quintile, hazard rate ratios (HRRs) were lowest for women in the highest quintile (HRR, 0.58; 95% confidence interval [CI], 0.46-0.74) for total physical activity and
PHYSICAL ACTIVITY AND MORTALITY AMONG OLDER WOMEN

Table 2. Hazard Rate Ratios for All-Cause, CVD, and Cancer Mortality by Quintiles of Total Physical Activity and Walking at Baseline*

<table>
<thead>
<tr>
<th>Quintile (kcal/wk)</th>
<th>All-Cause Mortality</th>
<th>CVD Mortality</th>
<th>Cancer Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age-Adjusted Rate per 1000 Person-Years</td>
<td>Hazard Rate Ratio (95% CI)</td>
<td>Age-Adjusted Rate per 1000 Person-Years</td>
</tr>
<tr>
<td>1 (&lt;163)</td>
<td>35.1</td>
<td>1.00</td>
<td>14.4</td>
</tr>
<tr>
<td>2 (163-503)</td>
<td>24.4</td>
<td>0.73 (0.64-0.82)</td>
<td>8.9</td>
</tr>
<tr>
<td>3 (504-1045)</td>
<td>24.3</td>
<td>0.77 (0.68-0.87)</td>
<td>8.7</td>
</tr>
<tr>
<td>4 (1046-1907)</td>
<td>19.7</td>
<td>0.62 (0.54-0.71)</td>
<td>7.5</td>
</tr>
<tr>
<td>5 (&gt;=1907)</td>
<td>20.6</td>
<td>0.68 (0.59-0.78)</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Walking

<table>
<thead>
<tr>
<th>Quintile (kcal/wk)</th>
<th>All-Cause Mortality</th>
<th>CVD Mortality</th>
<th>Cancer Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age-Adjusted Rate per 1000 Person-Years</td>
<td>Hazard Rate Ratio (95% CI)</td>
<td>Age-Adjusted Rate per 1000 Person-Years</td>
</tr>
<tr>
<td>1 (&lt;70)</td>
<td>32.2</td>
<td>1.00</td>
<td>13.0</td>
</tr>
<tr>
<td>2 (70-186)</td>
<td>28.5</td>
<td>0.91 (0.81-1.02)</td>
<td>11.3</td>
</tr>
<tr>
<td>3 (187-419)</td>
<td>22.6</td>
<td>0.78 (0.68-0.88)</td>
<td>7.6</td>
</tr>
<tr>
<td>4 (420-897)</td>
<td>20.5</td>
<td>0.71 (0.63-0.82)</td>
<td>7.7</td>
</tr>
<tr>
<td>5 (&gt;=898)</td>
<td>20.5</td>
<td>0.71 (0.62-0.82)</td>
<td>7.3</td>
</tr>
</tbody>
</table>

Hazard Rate Ratios for All-Cause, CVD, and Cancer Mortality by Quintiles of Total Physical Activity and Walking at Baseline*

Abbreviations: CI, confidence interval; CVD, cardiovascular disease.

*All analyses controlled for age, smoking, body mass index, stroke, diabetes, hypertension, and self-rated health at baseline. In additional analyses controlling for coronary heart disease measured at the second visit (n = 7515), hazard rate ratios for all-cause mortality for women in quintiles 2 through 5 of total physical activity, respectively, compared with quintile 1, were 0.70 (95% CI, 0.60-0.81), 0.81 (95% CI, 0.70-0.94), 0.64 (95% CI, 0.48-0.75), and 0.69 (95% CI, 0.59-0.81). For CVD mortality, relative risk estimates compared with quintile 1 were 0.61 (95% CI, 0.48-0.78), 0.77 (95% CI, 0.61-0.98), 0.62 (95% CI, 0.48-0.81), and 0.63 (95% CI, 0.48-0.83).

Mortality due to CVD tended to be lowest in women with the greatest increases in physical activity; compared with women who became active at both visits, all-cause HRs for those who increased from the bottom 2 quintiles to the third, fourth, and fifth quintiles were 0.85 (95% CI, 0.48-1.50), 0.69 (95% CI, 0.36-1.30), and 0.32 (95% CI, 0.12-0.87), respectively. There was little dose-response relationship between physical activity change and all-cause and cancer mortality, however; HRs for those who increased to the third through fifth quintiles, respectively, were 0.54 (95% CI, 0.36-0.83), 0.58 (95% CI, 0.36-1.00), 0.80 (95% CI, 0.42-1.47), and 1.05 (95% CI, 0.63-1.75).

Changes in Physical Activity

Compared with women who were sedentary at both visits, sedentary women who became active had significantly reduced mortality risk due to all causes (HRR, 0.52; 95% CI, 0.40-0.69), CVD (HRR, 0.64; 95% CI, 0.42-0.97), and cancer (HRR, 0.49; 95% CI, 0.29-0.84) after controlling for age, BMI, smoking, comorbid conditions, and baseline physical activity (TABLE 3 and FIGURE). Adjusting for propensity scores yielded similar results. The HRs associated with increasing physical activity were lowest in the first 2 years of follow-up for each outcome (HRR range, 0.38-0.44 across the 3 outcomes) and increased slightly during the middle years (HRR range, 0.48-0.79) and later years (HRR range, 0.60-0.72).

HRR, 0.61; 95% CI, 0.49-0.78 for walking). Although women in the second and fourth quintiles of total activity had reduced cancer mortality risk (HRR, 0.77 and 0.62, respectively), associations were less consistent and walking was not associated with cancer mortality risk. The HRs were not appreciably altered when we examined the subsample for whom coronary heart disease data were available (see Table 2 footnote).

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0.38-0.89), and 0.43 (95% CI, 0.25-0.73) for all-cause mortality and 0.59 (95% CI, 0.28-1.28), 0.37 (95% CI, 0.14-1.00), and 0.51 (95% CI, 0.20-1.25) for cancer mortality.

Women reporting high levels of total physical activity at both visits also had significant reductions in mortality due to all causes (HRR, 0.68; 95% CI, 0.56-0.82) and CVD (HRR, 0.62; 95% CI, 0.44-0.88) but not cancer (Figure). Mortality rates for women who decreased their activity levels did not differ significantly from those of continually sedentary women, except for cancer mortality, for which they had a lower mortality rate (HRR, 0.61; 95% CI, 0.42-0.90).

Stratification by propensity score quintile allowed for examination of the association of increasing physical activity with strata of women who had relatively homogeneous health status (Table 4). We found that the association between physical activity changes and lower mortality were generally consistent regardless of risk status (propensity score tertile). However, exclusion of the first 2 years of follow-up led to a notable attenuation of the association among the highest-risk women (ie, those with worse health status). The association between increasing activity level and mortality reduction also tended to be stronger among women younger than 75 years than among women aged at least 75 years (Table 5), particularly when we excluded women with less than 2 years of follow-up (HRR, 0.23; 95% CI, 0.10-0.53 for <75 years; HRR, 0.77; 95% CI, 0.55-1.08 for ≥75 years).

When we examined the relationship between absolute changes in physical activity levels (rather than quintile shifts), women who increased their activity levels had a 36% lower mortality (HRR, 0.64; 95% CI, 0.53-0.77) than women who had maintained their physical activity levels (Table 5); this association was stronger among women with large increases in physical activity (HRR, 0.54; 95% CI, 0.41-0.70) and existed in both age strata. However, the association between increases in physical activity and lowered mortality was attenuated among older women when we excluded the first 2 years of follow-up. Additionally, large decreases in physical activity were associated with increased mortality among women aged at least 75 years (HRR, 1.43; 95% CI,

![Figure. Cumulative Incidence of Mortality by Change in Total Physical Activity by Years of Follow-up](image)

### Table 4. Mortality Risk and Health Status Characteristics Associated With Increasing Physical Activity, Stratified by Tertile of Propensity Score

<table>
<thead>
<tr>
<th>Health Status Based on Propensity Score</th>
<th>Staying Sedentary (n = 534)</th>
<th>Became Active (n = 469)</th>
<th>Staying Sedentary (n = 761)</th>
<th>Became Active (n = 242)</th>
<th>Staying Sedentary (n = 903)</th>
<th>Became Active (n = 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics at follow-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>74.8 (3.5)</td>
<td>74.4 (3.2)</td>
<td>77.1 (4.3)</td>
<td>76.8 (4.6)</td>
<td>80.9 (5.6)</td>
<td>80.3 (5.6)</td>
</tr>
<tr>
<td>Body mass index, mean (SD)*</td>
<td>25.6 (4.2)</td>
<td>25.5 (4.0)</td>
<td>27.2 (4.9)</td>
<td>27.2 (4.8)</td>
<td>28.0 (5.6)</td>
<td>27.6 (5.3)</td>
</tr>
<tr>
<td>Smoking, No. (%)</td>
<td>27 (5.1)</td>
<td>27 (5.8)</td>
<td>57 (7.5)</td>
<td>14 (5.8)</td>
<td>82 (9.1)</td>
<td>9 (0.0)</td>
</tr>
<tr>
<td>Diabetes, No. (%)</td>
<td>21 (3.9)</td>
<td>21 (4.5)</td>
<td>57 (7.5)</td>
<td>18 (7.4)</td>
<td>115 (12.7)</td>
<td>9 (0.0)</td>
</tr>
<tr>
<td>CVD or COPD, No. (%)</td>
<td>104 (19.5)</td>
<td>72 (15.4)</td>
<td>215 (28.3)</td>
<td>68 (28.1)</td>
<td>444 (49.2)</td>
<td>45 (45.0)</td>
</tr>
<tr>
<td>Cancer, No. (%)</td>
<td>102 (19.1)</td>
<td>98 (20.9)</td>
<td>148 (19.5)</td>
<td>46 (19.0)</td>
<td>198 (21.9)</td>
<td>18 (18.0)</td>
</tr>
<tr>
<td>Fair/poor self-rated health status, No. (%)</td>
<td>24 (4.5)</td>
<td>22 (4.7)</td>
<td>130 (17.1)</td>
<td>36 (14.9)</td>
<td>417 (46.2)</td>
<td>42 (42.0)</td>
</tr>
</tbody>
</table>

Mortality, HRR (95% CI)†

- All-cause
  - Staying Sedentary (n = 534): 1.00 (0.55-0.91)
  - Became Active (n = 469): 1.00 (0.50-0.82)
  - Staying Sedentary (n = 761): 1.00 (0.56-1.00)
  - Became Active (n = 242): 1.00 (0.45-0.81)
  - Staying Sedentary (n = 903): 1.00 (0.64-1.04)
  - Became Active (n = 100): 1.00 (1.01-1.70)

Abbreviations: CI, confidence interval; COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; HRR, hazard rate ratio.

*Body mass index is calculated as weight in kilograms divided by the square of height in meters.
†Hazard rate ratios controlled for propensity score within health risk strata.

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PHYSICAL ACTIVITY AND MORTALITY AMONG OLDER WOMEN

Table 5. Hazard Rate Ratios Associated With Changes in Physical Activity Levels, Stratified by Age*

<table>
<thead>
<tr>
<th>Change in physical activity, baseline to follow-up</th>
<th>Aged 65–74 y</th>
<th>Entire Follow-up</th>
<th>Aged ≥75 y</th>
<th>Entire Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary to sedentary</td>
<td>2198 (29)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Active to sedentary</td>
<td>1410 (19)</td>
<td>0.92 (0.77–1.09)</td>
<td>0.63 (0.42–0.96)</td>
<td>0.79 (0.48–1.28)</td>
</tr>
<tr>
<td>Sedentary to active</td>
<td>811 (11)</td>
<td>0.52 (0.40–0.69)</td>
<td>0.33 (0.18–0.59)</td>
<td>0.23 (0.10–0.53)</td>
</tr>
<tr>
<td>Active to active</td>
<td>3134 (41)</td>
<td>0.68 (0.56–0.82)</td>
<td>0.60 (0.40–0.88)</td>
<td>0.62 (0.38–1.00)</td>
</tr>
</tbody>
</table>

*Hazard rate ratios controlled for age, smoking, body mass index, stroke, diabetes, hypertension, self-rated health status, coronary heart disease, cancer, chronic obstructive pulmonary disease, incident hip fracture, and baseline physical activity.

1.07–1.90) but were not associated with mortality among women younger than 75 years.

COMMENT

In this large population of older white women, both being physically active and becoming active were associated with substantially lower mortality rates. Notably, sedentary white women who increased their physical activity levels to the equivalent of about 1 mile/d of walking between baseline and a follow-up visit 6 years later had approximately 40% to 50% lower all-cause, CVD, and cancer mortality rates than chronically sedentary white women. We found similar reductions in all-cause and CVD mortality rates among white women who were consistently active throughout the study. However, recent physical activity levels were a more important predictor of longevity than past levels; previously sedentary white women who became active had a similar mortality rate as those who were already active, whereas active white women who became sedentary had a mortality risk similar to those who were sedentary all along.

Increased longevity associated with increasing physical activity could arise from many factors, including reductions in CVD risk factors and events, improved cardiorespiratory fitness,4,9,19,20 and reduced risk of falls, osteoporotic fractures, and physical disability.9,27,30,31 We also found that increasing physical activity was associated with mortality reductions in all but the highest-risk white women. However, even the low- and moderate-risk women in the study sample had a high prevalence of comorbid conditions such as hypertension, diabetes, CVD, and functional difficulties. Thus, our study may indicate that physical activity works as much by slowing decline, enhancing recovery, and extending life in those who already have chronic conditions as by preventing onset of new disease. Such a finding is consistent with previous meta-analyses relating exercise-based cardiac rehabilitation to CVD mortality32 as well as observational studies among diabetic persons relating higher physical activity and fitness to fewer cardiovascular events and deaths.33,34

Whether increasing physical activity has a similar association with lower mortality across the full age range of older women is less clear, as we found a slightly weaker relationship among white women aged at least 75 years. This may be due in part to a survival bias, wherein the oldest white women are particularly hardy and among whom variation in physical activity may play a lesser role in influencing longevity. Additionally, our physical activity questionnaire may have been less sensitive to physical activities commonly performed by the oldest white women. These concerns, combined with the lack of comparable studies, indicate a need for future studies to more closely examine the effects of physical activity among the oldest segment of the population.

Few studies have examined the association between late-life physical activity changes and mortality. In a population-based sample of 1405 Swedish women,35 changes in physical activity levels were positively associated with longevity, but this appeared to be driven primarily by women who decreased their physical activity levels having increased mortality. Women who increased their physical activity levels did not have reduced mortality, leading the authors to conclude that it may be the maintenance of physical activity (ie, preventing decreases) that is most important for longevity in older age. One other study conducted among a small sample of older men (aged 65–74 years) found that those who increased their physical activity levels had an increased risk of ischemic heart disease mortality.35 Results from at least 4 other younger sample populations, however, have associated increases in physical activity or fitness levels during...
middle age with reduced all-cause and CVD mortality.17–20

Previous studies have indicated that observational studies do not systematically overestimate effects relative to randomized controlled trials.36,37 Notable exceptions to this, however, are the recently published large randomized controlled trials that showed no benefit of hormone replacement therapy on CVD outcomes, contradicting earlier observational studies.38,39 The controversy over hormone replacement therapy may stimulate a closer examination of the large body of observational studies associating physical activity levels with longevity as well. Like most studies of physical activity and mortality, these were secondary analyses using data from a large cohort study. Accordingly, our study also cannot rule out the influence of selection biases, residual confounding, or findings due to chance. We found changes in physical activity to be more consistently associated with cancer mortality than baseline physical activity, raising the question of whether a higher prevalence of undetected cancer among chronically sedentary white women explained the association of physical activity increases with reduced mortality. Recent systematic reviews suggest that regular physical activity is causally associated with reduced colon and breast cancer risk.40,41 But that data related to other cancer sites for women are insufficient to make conclusions.

The potential for similar biases and residual confounding also exists for CVD mortality, as we found weaker effects in later years of follow-up than in the early years. However, mortality reductions remained substantial in later years, and our analytic approach was conservative in that we controlled for comorbidities at the follow-up visit rather than the baseline visit. We also found similar results when we controlled for and stratified by propensity scores. However, these analyses cannot account for variation in health not measured by the study or control for other subclinical disease that could have influenced both the ability to increase physical activity levels and mortality risk. Considering these limitations and the widespread credit given to physical activity’s health influence,9 it is unfortunate that there has never been an adequately powered randomized controlled trial to verify the independent influence of physical activity on major disease outcomes or death and determine whether selection factors influence observational studies of physical activity.

Our study may have been limited by our dependence on self-reported physical activity and our inability to assess the effects of lower-level nonleisure activities. However, we observed broad distributions for physical activities that are common among older women (walking, gardening, nonleisure walking) and estimates of physical activity using these measures have been shown to be reliable among postmenopausal women.52 There was also slight variation in the physical activity questionnaires used at baseline and follow-up. Although we excluded information about high-intensity activities to make the measures of physical activity equivalent, there may have been some difference in the absolute levels of physical activity that resulted from these slightly different formats. Another potential limitation is that changes in physical activity levels could indicate a regression to the mean. If so, the group reporting increasing physical activity levels may include habitually active women who were simply misclassified as sedentary at baseline. Previous studies have provided some validation for repeated physical activity assessments, however, showing that reported changes in physical activity are accompanied by significant improvements in cardiorespiratory fitness.39 Accordingly, it seems unlikely that changes in physical activity are simply due to reporting error or misclassification. Finally, we had less power for our evaluation of cancer mortality than for all-cause and CVD mortality. In post hoc power calculations for analyses of changes in physical activity, we estimate that we had 80% power to identify reductions of 23%, 38%, and 50% for all-cause mortality, CVD, and cancer mortality, respectively, and 46% and 28% all-cause mortality reductions among those younger than and at least 75 years of age, respectively.

Our finding that being consistently physically active and adopting a physically active lifestyle are each associated with longevity in older white women are important because the population of older women in the United States is projected to double in the next 30 years19 and more than one third are now sedentary.22 Modest increases in physical activity could have wide-ranging benefits ranging from improved risk factors to reduced disability. Our findings suggest these benefits may translate into substantial reductions in mortality, indicating a need to identify effective modes of enhancing walking and other low-intensity activities among older white women as well as effective health system–, community–, and environmentally based approaches to enhance physical activity. Examination of these issues in the form of randomized controlled trials would help translate these findings to the clinical setting, determine the mechanisms for such effects, and rule out the influence of self-selection factors.

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