Original Contribution

Patterns of 12-Year Change in Physical Activity Levels in Community-Dwelling Older Women: Can Modest Levels of Physical Activity Help Older Women Live Longer?


* Correspondence to Dr. Qian-Li Xue, Department of Medicine, Johns Hopkins University School of Medicine, 2024 E. Monument Street, Suite 2-700, Baltimore, MD 21205 (e-mail: qxue@jhsph.edu).

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Few studies have addressed changes in physical activity participation over time among the elderly. The authors hypothesized that there were distinct trajectories of physical activity level over time and identifiable predictors of such trajectories, as well as that the maintenance of regular physical activity, even below recommended levels, was associated with lower mortality risk. Using longitudinal data (1994–2009) from 433 initially high-functioning older women aged 70–79 years at baseline, a joint latent class and survival mixture model identified 4 activity trajectory classes: always active (16.6%), fast declining (19.2%), stable moderate (32.3%), and always sedentary (31.9%). Obesity, coronary artery disease, chronic obstructive pulmonary disease, depressive symptoms, low self-efficacy, mobility disability, and low energy were associated with sedentary behavior and/or a fast decline in activity. Women in the fast declining and always sedentary classes had hazard ratios for death of 2.34 (95% confidence interval: 1.20, 4.59) and 3.34 (95% confidence interval: 1.72, 6.47), respectively, compared with the always active class; no mortality difference was found between the stable moderate and always active groups (hazard ratio = 1.24, 95% confidence interval: 0.63, 2.47). Our findings suggest that physical activity does not have to be vigorous to be beneficial and that the gain may be the greatest among women who reported the lowest levels of activity.

Abbreviations: ACSM, American College of Sports Medicine; CDC, Centers for Disease Control and Prevention; CI, confidence interval; COPD, chronic obstructive pulmonary disease; HABC, Health, Aging and Body Composition Study; HR, hazard ratio; NHIS, National Health Interview Survey; WHAS, Women's Health and Aging Study.

There is compelling evidence of the benefits of physical activity for older adults. Regular exercise and leisure-time physical activities are consistently associated with anti-inflammatory effects (1), regulation of anabolic hormones (2), and protection from cognitive impairment (3–5), geriatric syndromes (e.g., falls, frailty) (6, 7), decline in physical functioning (8–10), and certain diseases (11). However, despite the wide-ranging health benefits of physical activity, the majority of older US adults are inactive; only 16% of individuals aged 65–74 years report participating in the recommended 30 minutes or more of moderate physical activity on 5 or more days per week (12).

Few studies have addressed long-term changes in physical activity participation over time in older adults (13, 14). A cross-sectional measurement is limited in capturing an individual’s true average activity over a given interval. We hypothesized that the maintenance of regular physical activity over time, even if below the recommended level, is a marker of greater physiologic reserve and status and therefore also should be associated with a lower risk of
mortality. To test this hypothesis, we used longitudinal data from the Women’s Health and Aging Study (WHAS) II to 1) characterize patterns of change in physical activity level over time in a representative sample of initially high-functioning older women, 2) assess the associations between patterns of change in physical activity level and all-cause mortality, and 3) identify predictors of change in physical activity.

MATERIALS AND METHODS
Study population

WHAS II is a prospective cohort study of 436 women aged 70–79 years who are representative of the two-thirds highest functioning women living in the community. Study eligibility criteria and recruitment are reported elsewhere (15). Interviews and physical examinations were conducted at baseline and at 6 follow-up visits (approximately 18 months apart except for the interval between the third and the fourth visit, which was, on average, 3 years). A median follow-up time of 12 years resulted between 1994 and 2009. The study was approved by the Johns Hopkins University Institutional Review Board. The analytic sample consisted of 433 women for whom we had data on physical activity levels at baseline. In longitudinal analyses, 95% and 67% of the 433 women contributed 2 or more and 5 or more measurements of physical activity, respectively, before study dropout or death.

Measures of physical activity

Physical activity level was assessed using a shortened version of the Minnesota Leisure Time Activities Questionnaire (16), which includes 4 exercise activities (walking for exercise, dancing, bowling and exercise (e.g., strengthening activities)) and 2 lifestyle activities (strenuous household (e.g., scrubbing) and outdoor (e.g., gardening) chores). Level of participation in each activity was assessed by self-reported frequency and duration of participation during the past 2 weeks.

We compared 3 categorical measures of physical activity by using both published and population-based cutoffs. First, we used the time-based criteria established by the Centers for Disease Control and Prevention and the American College of Sports Medicine: inactive (0 minute/week), moderately active (>0 to <150 minutes/week), and very active (≥150 minutes/week) (termed CDC/ACSM criteria). Second, as in the Health, Aging, and Body Composition Study (7), we classified a woman as inactive if she expended fewer than 1,000 kcal/week in exercise activity and 0 kcal/week in lifestyle activity, as lifestyle active if she expended more than 0 kcal/week in lifestyle activity and less than 1,000 kcal/week in exercise activity, and as exercise active if she expended 1,000 kcal/week or more in exercise activity (termed HABC criteria). Third, we calculated kilocalorie expenditure per kilogram of body weight per day (kcal/day/kg) over a 2-week period by multiplying activity-specific metabolic equivalents of task value by the average number of minutes per day spent in the activity and summed across the 6 activities. Using the cutoffs defined by the National Health Interview Survey (17), we then classified activity level into 3 categories: inactive (<1.5 kcal/day/kg), moderately active (≥1.5 and <3 kcal/day/kg), and very active (≥3 kcal/day/kg) (termed NHIS criteria).

Total mortality

Data on all-cause mortality were obtained through follow-up interviews with proxies, obituaries, and matching with the National Death Index, with the most recent update completed on January 28, 2009. Thirty-four percent of the 433 women (n = 149) died during the follow-up period, with an incidence rate of 31 per 1,000 person-years.

Covariates

Covariates included age, race classified as white versus nonwhite, years of education by self-report, and body mass index (weight (kg)/height (m)²) categorized as underweight (<18.5), normal weight (18.5–24.9), overweight (25–29.9), or obese (≥30). Self-report of the presence or absence of 14 major chronic diseases at baseline was adjudicated by physicians based on predefined criteria (18) (Table 1). The number of “definite” diseases out of 14 was used as a measure of disease burden. Smoking status was classified based on self-report as current, former, or never smoker. Depressive symptoms were assessed using the 30-item Geriatric Depression Scale (19). Mobility disability was defined as any self-reported difficulty in 1 or more of the following 4 tasks: walking 2–3 blocks, climbing 10 steps, getting in or out of bed/chairs, or doing heavy housework. A participant was considered to be living alone if the household size was 1. Self-efficacy was ascertained by asking, “Do you, in general, feel helpless?” with possible responses of strongly disagree, disagree, and agree to strongly agree, corresponding to high, medium, low self-efficacy, respectively. Energy level was rated by participants on a Likert scale from 0 to 10, where 0 denoted no energy and 10 denoted “the most energy that you have ever had.”

Data analysis

We began by comparing prevalence estimates of activity status by study visit and by classification system (i.e., NHIS, HABC, and CDC/ACSM). We used a Cox proportional hazards model to analyze the association between baseline physical activity level and all-cause mortality among women who reported any activity at baseline (n = 401) after adjustment for age, race, and educational level. We modeled the baseline activity level as a continuous variable in kcal/day/kg with both a linear and quadratic term to account for nonlinear trend. To determine which of the 3 classification systems for activity status was most appropriate for capturing meaningful changes in activity level over time while taking into account measurement error due to self-report, we first analyzed transitions between different physical activity states using stationary and first-order Markov models for each classification system (20, 21). Death was treated as an
### Table 1. Summary of Baseline Characteristics by Physical Activity Trajectory Profiles Derived From the Joint Latent Class and Survival Mixture Analysis, Women’s Health and Aging Study II, 1994–2009

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. %</th>
<th>No. %</th>
<th>No. %</th>
<th>No. %</th>
<th>No. %</th>
<th>No. %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, years</strong></td>
<td>73.9 (2.8)</td>
<td>74.1 (3.1)</td>
<td>73.3 (2.7)</td>
<td>74.3 (2.6)</td>
<td>74.2 (2.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>White</td>
<td>352 (81.3)</td>
<td>64 (88.9)</td>
<td>108 (77.1)</td>
<td>70 (84.3)</td>
<td>110 (79.7)</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>80 (18.7)</td>
<td>7 (9.7)</td>
<td>32 (22.9)</td>
<td>13 (15.7)</td>
<td>28 (20.3)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1 (0.2)</td>
<td>1 (1.4)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td><strong>Years of education</strong></td>
<td>12.5 (3.3)</td>
<td>12.2 (3.2)</td>
<td>12.5 (3.1)</td>
<td>12.0 (3.6)</td>
<td>12.5 (3.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Living alone</strong></td>
<td>222 (51.3)</td>
<td>38 (52.8)</td>
<td>61 (43.6)</td>
<td>48 (57.8)</td>
<td>44 (31.9)</td>
<td></td>
</tr>
<tr>
<td><strong>Body mass index</strong></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>&lt;18.5</td>
<td>14 (3.2)</td>
<td>5 (6.9)</td>
<td>3 (2.1)</td>
<td>2 (2.4)</td>
<td>4 (2.9)</td>
<td></td>
</tr>
<tr>
<td>18.5–24.9</td>
<td>154 (36.6)</td>
<td>32 (44.4)</td>
<td>48 (34.3)</td>
<td>27 (32.5)</td>
<td>47 (34.1)</td>
<td></td>
</tr>
<tr>
<td>25–29.9</td>
<td>164 (37.9)</td>
<td>28 (38.9)</td>
<td>54 (38.6)</td>
<td>40 (48.2)</td>
<td>42 (30.4)</td>
<td></td>
</tr>
<tr>
<td>≥30</td>
<td>99 (22.9)</td>
<td>7 (9.7)</td>
<td>34 (24.3)</td>
<td>14 (16.9)</td>
<td>44 (31.9)</td>
<td></td>
</tr>
<tr>
<td><strong>Self-reported health</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>69 (15.9)</td>
<td>14 (19.4)</td>
<td>29 (20.7)</td>
<td>9 (10.8)</td>
<td>17 (12.3)</td>
<td></td>
</tr>
<tr>
<td>Very good</td>
<td>145 (33.5)</td>
<td>31 (43.1)</td>
<td>50 (35.7)</td>
<td>33 (39.8)</td>
<td>31 (22.5)</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>173 (40.0)</td>
<td>25 (34.7)</td>
<td>46 (32.9)</td>
<td>32 (38.6)</td>
<td>70 (50.7)</td>
<td></td>
</tr>
<tr>
<td>Fair/poor</td>
<td>46 (10.7)</td>
<td>2 (2.8)</td>
<td>15 (10.7)</td>
<td>9 (10.8)</td>
<td>20 (14.5)</td>
<td></td>
</tr>
<tr>
<td><strong>No. of diseases</strong></td>
<td>1.6 (1.0)</td>
<td>1.3 (0.9)</td>
<td>1.5 (1.0)</td>
<td>1.5 (1.0)</td>
<td>1.8 (1.1)</td>
<td></td>
</tr>
<tr>
<td><strong>Coronary artery disease</strong></td>
<td>66 (15.2)</td>
<td>4 (5.6)</td>
<td>20 (14.3)</td>
<td>10 (12.1)</td>
<td>32 (23.2)</td>
<td></td>
</tr>
<tr>
<td><strong>Chronic obstructive pulmonary disease</strong></td>
<td>100 (23.1)</td>
<td>9 (12.5)</td>
<td>28 (20.0)</td>
<td>23 (27.7)</td>
<td>40 (29.0)</td>
<td></td>
</tr>
<tr>
<td><strong>Diabetes</strong></td>
<td>33 (7.6)</td>
<td>5 (6.9)</td>
<td>10 (7.1)</td>
<td>3 (3.6)</td>
<td>15 (10.9)</td>
<td></td>
</tr>
<tr>
<td><strong>Osteoarthritis</strong></td>
<td>288 (66.5)</td>
<td>48 (66.7)</td>
<td>89 (63.6)</td>
<td>56 (67.5)</td>
<td>95 (68.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Cancer</strong></td>
<td>36 (8.3)</td>
<td>7 (9.7)</td>
<td>9 (6.4)</td>
<td>7 (8.4)</td>
<td>13 (9.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Physical activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Inactive</td>
<td>185 (42.7)</td>
<td>11 (15.3)</td>
<td>43 (30.7)</td>
<td>22 (26.5)</td>
<td>109 (79.0)</td>
<td></td>
</tr>
<tr>
<td>Moderately active</td>
<td>99 (22.9)</td>
<td>17 (23.6)</td>
<td>61 (43.6)</td>
<td>5 (6.0)</td>
<td>16 (12.0)</td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>149 (34.4)</td>
<td>44 (61.1)</td>
<td>36 (25.7)</td>
<td>56 (67.5)</td>
<td>13 (9.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Types of physical activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walk for exercise</td>
<td>243 (56.1)</td>
<td>54 (75.0)</td>
<td>78 (55.7)</td>
<td>49 (59.0)</td>
<td>62 (44.9)</td>
<td></td>
</tr>
<tr>
<td>Exercise</td>
<td>85 (19.6)</td>
<td>23 (31.9)</td>
<td>31 (22.1)</td>
<td>19 (22.9)</td>
<td>12 (8.7)</td>
<td></td>
</tr>
<tr>
<td>Dancing</td>
<td>64 (14.8)</td>
<td>21 (29.2)</td>
<td>21 (15.0)</td>
<td>12 (14.5)</td>
<td>10 (7.2)</td>
<td></td>
</tr>
<tr>
<td>Bowling</td>
<td>24 (5.5)</td>
<td>9 (12.5)</td>
<td>6 (4.3)</td>
<td>9 (10.8)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Strenuous household chores</td>
<td>305 (70.4)</td>
<td>53 (73.6)</td>
<td>114 (81.4)</td>
<td>69 (83.1)</td>
<td>69 (50.0)</td>
<td></td>
</tr>
<tr>
<td>Strenuous outdoor chores</td>
<td>127 (29.3)</td>
<td>31 (43.1)</td>
<td>41 (29.3)</td>
<td>29 (34.9)</td>
<td>26 (18.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Smoking status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never smoker</td>
<td>237 (54.7)</td>
<td>43 (59.7)</td>
<td>79 (56.4)</td>
<td>48 (57.8)</td>
<td>67 (48.6)</td>
<td></td>
</tr>
<tr>
<td>Former smoker</td>
<td>152 (35.1)</td>
<td>22 (30.6)</td>
<td>46 (32.9)</td>
<td>30 (36.1)</td>
<td>54 (39.1)</td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td>44 (10.2)</td>
<td>7 (9.7)</td>
<td>15 (10.7)</td>
<td>5 (6.0)</td>
<td>17 (12.3)</td>
<td></td>
</tr>
<tr>
<td>Geriatric Depression Scale score</td>
<td>3 (1–6)</td>
<td>2 (1–3)</td>
<td>3 (1–5)</td>
<td>3 (1–5.5)</td>
<td>4 (2–7)</td>
<td></td>
</tr>
<tr>
<td>Geriatric Depression Scale score ≥ 10</td>
<td>36 (8.3)</td>
<td>0 (0)</td>
<td>14 (10.0)</td>
<td>5 (6.0)</td>
<td>17 (12.3)</td>
<td></td>
</tr>
<tr>
<td>Mobility disability</td>
<td>133 (30.7)</td>
<td>13 (18.1)</td>
<td>39 (27.9)</td>
<td>17 (20.5)</td>
<td>64 (46.4)</td>
<td></td>
</tr>
</tbody>
</table>
absorbing state, with zero probability of all other activity states after death has occurred. From this model, we estimated for each classification system a matrix of conditional probabilities of transitioning from state $j$ (e.g., moderately active) at time $t - 1$ to state $k$ (e.g., inactive) at time $t$ and then used this transition matrix to calculate the Shannon conditional entropy (22, 23), which is a measure of uncertainty of an outcome at time $t$ given the value of the same outcome at time $t - 1$. A larger value of conditional entropy for a transition matrix indicates greater overall unpredictability in changes in activity status over time.

We identified patterns of change in physical activity over time using a latent class analysis of the within-subject repeated measurements of activity status. The latent class analysis hypothesizes the existence of subpopulations of older women with distinct patterns of activity trajectories. The analysis then aims to determine the number of subpopulations (“trajectory classes”) and estimate for each subpopulation its prevalence in the overall population and the proportions who were inactive, moderately active, and very active at each visit within each trajectory class. We identified 4 trajectory classes based on Lo-Mendell-Rubin adjusted likelihood ratio test (24) and scientific plausibility and meaningfulness of the resulting trajectory patterns.

To account for missing data, the latent class analysis model was fit using the full information maximum likelihood estimator that is unbiased under the assumption of data missing at random (25). However, missing data on physical activity level due to death is arguably informative rather than missing at random, so to address this, we applied a mixture survival model (26) that combines the latent class analysis of the physical activity trajectories and the time-to-event analysis of all-cause mortality in relation to the trajectory classes. The baseline hazard of mortality was modeled as a nonparametric step function varying by trajectory classes.

After fitting the mixture survival model, we estimated the person-specific probabilities of being in each of the classes given their observed profile of activity status over time and then assigned each subject to the class with the highest probability. Next, we used Cox proportional hazards model to assess the associations between the activity trajectory classes and all-cause mortality after adjusting for baseline age, race, and educational level. Finally, we identified predictors of trajectory classes by regressing an individual’s class membership against baseline demographic and health characteristics separately and jointly using multinomial logistic models. MPLUS, version 6 (Muthén & Muthén, Los Angeles, California) and Stata, version 9.2 (StataCorp LP, College Station, Texas) were used for model fitting.

RESULTS

Table 1 summarizes the demographic and health characteristics of the study sample at baseline. Of the 433 women included in this study, 19% were nonwhite, 61% were either overweight or obese, 31% reported mobility disability, and 8% reported 10 or more depressive symptoms. On average, the cohort was 74 years of age and had 12.5 years of education and 1.6 chronic diseases.

Physical activity participation at baseline

At baseline, 60% of the women met the CDC/ACSM recommended level of moderate intensity physical activity

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total Sample (n = 433)$^b$</th>
<th>Always Active (n = 72, 16.6%)</th>
<th>Stable Moderate (n = 140, 32.3%)</th>
<th>Fast Declining (n = 83, 19.2%)</th>
<th>Always Sedentary (n = 138, 31.9%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.  %</td>
<td>No.  %</td>
<td>No.  %</td>
<td>No.  %</td>
<td>No.  %</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>262  60.5</td>
<td>53   73.6</td>
<td>87   62.1</td>
<td>48   57.8</td>
<td>74   53.6</td>
</tr>
<tr>
<td>Medium</td>
<td>119  27.5</td>
<td>14   19.4</td>
<td>40   28.6</td>
<td>21   25.3</td>
<td>44   31.9</td>
</tr>
<tr>
<td>Low</td>
<td>52   12.0</td>
<td>5    6.9</td>
<td>13   9.3</td>
<td>14   16.9</td>
<td>20   14.5</td>
</tr>
<tr>
<td>Energy level$^d$</td>
<td>8 (7–9)</td>
<td>8.5 (7–10)</td>
<td>8 (7–9)</td>
<td>8 (7–9)</td>
<td>7 (6–8)</td>
</tr>
</tbody>
</table>

$^a$ Estimated from the joint latent class and survival model.

$^b$ Three of the 436 women were missing data on activity measures and were therefore excluded from the analysis.

$^c$ Values are mean (standard deviation).

$^d$ Percentages may not add up to 100 because of missing data.

$^e$ Weight (kg)/height (m)$^2$.

$^f$ Presence of definite diseases, including angina pectoris/myocardial infarction, congestive heart failure, peripheral artery disease, hip fractures, osteoarthritis of the hip, knee and/or hand, Parkinson's disease, rheumatoid arthritis, osteoporosis, stroke, pulmonary diseases, diabetes mellitus, cancer, spinal stenosis, and disc disease.

$^g$ Based on the National Health Interview Survey criteria.

$^h$ Values are median (interquartile range).
of 150 minutes/week. They engaged in various activities: 56% of women reported walking for exercise, 70% reported performing strenuous household chores, 29% reported performing strenuous outdoor chores, and 20% reported performing regular exercises. Dancing (15%) and bowling (6%) were the least frequent activities.

The proportions of women classified as inactive, moderately active, and very active varied substantially across the 3 different classification systems. For example, 42.7% of women were inactive by the NHIS criteria, whereas only 20.2% and 7.4% were inactive by the HABC and CDC/ACSM criteria, respectively. The estimates of conditional entropy were 1.65, 1.11, and 0.90 for the CDC/ACSM, HABC, and NHIS criteria, respectively. We therefore selected the measure with the smallest entropy, that is, the NHIS criteria, for the longitudinal analysis. By the NHIS criteria, 34%, 23%, and 43% were classified as being active, moderately active, and inactive at baseline, respectively.

**Baseline level of physical activity and all-cause mortality**

Women who reported no activity participation at baseline \((n = 32, 7.4\%)\) were twice as likely to die over the 12-year follow-up period than were women who reported any physical activity after adjustment for age, race, and educational level (hazard ratio \((HR) = 2.15, 95\%\) confidence interval \((CI) = 1.31, 3.53\)). Moreover, there was a nonlinear relation between baseline levels of activity modeled as a continuous variable (in kcal/day/kg) and mortality risk (Figure 1). Compared with women who met the 150 minutes/week guideline, which is equivalent to approximately 1,000 kcal/week for an individual weighing 60 kg or 2.38 kcal/day/kg, as denoted by the vertical dashed line). The curve represents the age-, race-, and educational level-adjusted relative mortality hazards across activity levels, and the bars indicate their 95% confidence intervals. The y-axis was transformed so that, for example, the graphic display of an increase in risk of the magnitude of 2 (hazard ratio = 2) would be equivalent to that of a decrease in risk of the same magnitude (hazard ratio = 0.5) in terms of scale size.

**Change in physicality activity over time**

Using the NHIS criteria, we found that there was, in general, a decline in the proportion of women who remained very active over time, from 34% at baseline (visit 1) to 18% at visit 7; over this period, the prevalence of inactivity increased from 43% at baseline to 62% at visit 7 (Figure 2A). With regard to specific activities, participation declined most in walking and household chores, with an average rate of decline of 3–5 minutes/year, followed by strenuous outdoor chores at a rate of 2.7 minutes/year (Figure 2B). The changes in the other activities were minimal.

The joint latent class and survival mixture model identified 4 activity trajectory classes over the 12-year follow-up period: 1) most active at baseline and staying active (“always active”), 2) active at baseline but becoming inactive (“fast declining”), 3) moderately active throughout (“stable moderate”), and 4) least active at baseline and staying inactive (“always sedentary”). The estimates of class prevalence were 16.6%, 19.2%, 32.3%, and 31.9% for classes 1–4, respectively (Figure 3).

**Physical activity trajectory and all-cause mortality**

There was a stepwise association between low or decreasing levels of physical activity and increasing risk of mortality (Figure 4). After adjustment for age, race, educational level, and NHIS activity status at baseline, the mortality hazards for women in the fast declining and always sedentary classes were 2.34 (95% CI: 1.20, 4.59) and 3.34 (95% CI: 1.72, 6.47) times higher than for women in the always active class, respectively; the mortality hazard for women in the stable moderate level, and NHIS activity status at baseline, the mortality hazards across activity levels, and the bars indicate their 95% confidence intervals. The y-axis was transformed so that, for example, the graphic display of an increase in risk of the magnitude of 2 (hazard ratio = 2) would be equivalent to that of a decrease in risk of the same magnitude (hazard ratio = 0.5) in terms of scale size.

**Predictors of physical activity trajectories**

Our multinomial logistic regression analyses (adjusted for age, race, and educational level) demonstrated that obesity, having self-reported fair or poor health, and mobility disability were associated with 3.97 (95% CI: 1.54, 10.26), 7.28 (95% CI: 1.40, 37.82), and 3.88 (95% CI: 1.94, 7.78) times higher odds, respectively, of being always sedentary.
than that of being always active (Table 2). Women with coronary artery disease and chronic obstructive pulmonary disease (COPD) were 5 (HR = 5.04, 95% CI: 1.69, 15.04) and 3 (HR = 2.97, 95% CI: 1.35, 6.57) times more likely to remain inactive than to stay active, and those with COPD were also 3 times (HR = 2.77, 95% CI: 1.18, 6.50) more likely to experience a fast decline in activity than to stay active. Every additional disease was associated with 70% increased odds of being always sedentary versus always active (HR = 1.70, 95% CI: 1.26, 2.30). Every additional depressive symptom was associated with a 19% increased odds of being stable moderate (HR = 1.19, 95% CI: 1.06, 1.34) or fast declining (HR = 1.19, 95% CI: 1.06, 1.34) and a 28% increased odds of being always sedentary (HR = 1.28, 95% CI: 1.14, 1.43) compared with that of being always active. Every unit increase in energy level...
<table>
<thead>
<tr>
<th>Predictor</th>
<th>Physical Activity Trajectory Profile&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Stable Moderate (n = 140, 32.3%)</th>
<th>Fast Declining (n = 83, 19.2%)</th>
<th>Always Sedentary (n = 138, 31.9%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR 95% CI</td>
<td>P Value&lt;sup&gt;c&lt;/sup&gt;</td>
<td>RR 95% CI</td>
<td>P Value</td>
</tr>
<tr>
<td>Age, years</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>70–74</td>
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<tr>
<td>75–80</td>
<td>0.60 0.33, 1.08 0.09 0.77 0.41, 1.47 0.42 1.05 0.59, 1.87 0.87</td>
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<tr>
<td>Race</td>
<td></td>
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<tr>
<td>White</td>
<td>1 Referent</td>
<td>1 Referent</td>
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<td>1 Referent</td>
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<tr>
<td>Nonwhite</td>
<td>2.06 0.87, 4.87 0.10 1.14 0.43, 3.02 0.80 1.88 0.79, 4.46 0.16</td>
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<tr>
<td>Years of education</td>
<td>0.96 0.87, 1.05 0.35 0.89 0.81, 0.99 0.03 0.96 0.88, 1.05 0.36</td>
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<tr>
<td>Living alone</td>
<td>0.67 0.37, 1.19 0.17 1.15 0.61, 2.19 0.66 1.04 0.58, 1.84 0.90</td>
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<tr>
<td>Body mass index&lt;sup&gt;e&lt;/sup&gt;</td>
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<tr>
<td>&lt;18.5</td>
<td>0.37 0.08, 1.68 0.20 0.46 0.08, 2.62 0.38 0.55 0.14, 2.21 0.40</td>
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<tr>
<td>18.5–24.9</td>
<td>1 Referent</td>
<td>1 Referent</td>
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<tr>
<td>25–29.9</td>
<td>1.22 0.64, 2.33 0.55 1.57 0.77, 3.20 0.22 1.03 0.53, 1.99 0.94</td>
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<tr>
<td>≥30</td>
<td>2.51 0.95, 6.59 0.06 1.83 0.62, 5.39 0.27 3.97 1.54, 10.26 0.004</td>
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<tr>
<td>Self-reported health</td>
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<td></td>
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<tr>
<td>Excellent</td>
<td>1 Referent</td>
<td>1 Referent</td>
<td>1 Referent</td>
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<tr>
<td>Very good</td>
<td>0.76 0.35, 1.68 0.50 1.63 0.61, 4.33 0.33 0.80 0.34, 1.92 0.62</td>
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<tr>
<td>Good</td>
<td>0.81 0.36, 1.86 0.62 1.76 0.64, 4.83 0.27 2.20 0.93, 5.19 0.07</td>
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<tr>
<td>Fair/poor</td>
<td>2.87 0.55, 14.91 0.21 5.69 0.95, 33.90 0.06 7.28 1.40, 37.82 0.02</td>
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<tr>
<td>No. of diseases&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1.24 0.92, 1.69 0.16 1.24 0.89, 1.73 0.21 1.70 1.26, 2.30 0.001</td>
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<tr>
<td>Coronary artery disease</td>
<td>2.96 0.96, 9.15 0.06 2.19 0.65, 7.40 0.21 5.04 1.69, 15.04 0.004</td>
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<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>1.83 0.81, 4.14 0.15 2.77 1.18, 6.50 0.02 2.97 1.35, 6.57 0.007</td>
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<td>Diabetes</td>
<td>0.86 0.27, 2.68 0.79 0.42 0.10, 1.86 0.25 1.40 0.48, 4.10 0.54</td>
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<tr>
<td>Osteoarthritis</td>
<td>1.01 0.55, 1.87 0.97 1.15 0.58, 2.29 0.68 1.20 0.64, 2.23 0.57</td>
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<tr>
<td>Cancer</td>
<td>0.67 0.24, 1.89 0.45 0.85 0.28, 2.58 0.78 0.96 0.36, 2.53 0.93</td>
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<td>Smoking status</td>
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<tr>
<td>Never smoker</td>
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<td>1 Referent</td>
<td>1 Referent</td>
<td>1 Referent</td>
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<tr>
<td>Former smoker</td>
<td>1.15 0.61, 2.19 0.66 1.34 0.67, 2.70 0.41 1.65 0.87, 3.12 0.12</td>
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<tr>
<td>Current smoker</td>
<td>1.12 0.42, 2.99 0.83 0.65 0.19, 2.24 0.50 1.61 0.61, 4.24 0.34</td>
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<tr>
<td>Geriatric Depression Scale score</td>
<td>1.19 1.06, 1.34 0.003 1.19 1.05, 1.34 0.005 1.28 1.14, 1.43 &lt;0.001</td>
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<tr>
<td>Mobility disability</td>
<td>1.81 0.88, 3.71 0.11 1.14 0.51, 2.58 0.75 3.88 1.94, 7.78 &lt;0.001</td>
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<td>Self-efficacy</td>
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<tr>
<td>High</td>
<td>1 Referent</td>
<td>1 Referent</td>
<td>1 Referent</td>
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<tr>
<td>Medium</td>
<td>1.84 0.90, 3.74 0.09 1.58 0.72, 3.49 0.26 2.27 1.12, 4.60 0.02</td>
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<tr>
<td>Low</td>
<td>1.74 0.58, 5.22 0.33 3.14 1.04, 9.46 0.04 2.91 1.02, 8.31 0.04</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy level&lt;sup&gt;g&lt;/sup&gt;</td>
<td>0.77 0.63, 0.93 0.006 0.81 0.66, 0.99 0.04 0.65 0.53, 0.78 &lt;0.001</td>
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</tbody>
</table>

Abbreviations: CI, confidence interval; RR, relative risk.

<sup>a</sup> Three of the 436 women were missing data on activity measures and were therefore excluded from the analysis.

<sup>b</sup> Estimated from the joint latent class and survival model.

<sup>c</sup> Two-sided P value.

<sup>d</sup> The always active class was the reference category.

<sup>e</sup> Weight (kg)/height (m)<sup>2</sup>.

<sup>f</sup> Presence of definite diseases, including angina pectoris/myocardial infarction, congestive heart failure, peripheral artery disease, hip fractures, osteoarthritis of the hip, knee and/or hand, Parkinson's disease, rheumatoid arthritis, osteoporosis, stroke, pulmonary diseases, diabetes mellitus, cancer, spinal stenosis, and disc disease.

<sup>g</sup> Energy level was rated on a Likert scale from 0–10, where 0 denoted no energy and 10 denoted the most energy that you have ever had.
was associated with a 23%, 19%, and 35% reduction in the
odds of being stable moderate (HR = 0.77, 95% CI: 0.63,
0.93), fast declining (HR = 0.81, 95% CI: 0.66, 0.99), and
always sedentary (HR = 0.65, 95% CI: 0.53, 0.78), respec-
tively, compared with that of being always active. Women
with low self-efficacy were about 3 times more likely to be
fast decliners (HR = 3.14, 95% CI: 1.04, 9.46) or remain
inactive (HR = 2.91, 95% CI: 1.02, 8.31) than to stay active.
Living alone was not associated with trajectory patterns.

When all the covariates in Table 2 except specific diseases
and self-efficacy (a component of Geriatric Depression
Scale) were included in a multivariable model, the effect
sizes for Geriatric Depression Scale score remained essen-
tially unchanged (results not shown). The associations of
obesity, number of diseases, mobility disability, and energy
level were attenuated but remained significant for having a
greater odds of being always sedentary versus always active
(results not shown).

**DISCUSSION**

We identified 4 distinct trajectories of change in leisure-
time physical activity levels over 12 years in community-
dwelling older women. To our knowledge, this is the first
longitudinal epidemiologic study that focused specifically
on characterizing physical activity participation over time
and examining predictors of such change in community-
dwelling, higher-functioning older women. Although similar
trajectory patterns were reported by Barnett et al. (27), their
results were limited to adults 18–60 years of age.

The observed curvilinear relation between lower levels
of physical activity and higher mortality risk suggests that
although any amount of increase could be beneficial, the
gain was the greatest among women reporting the lowest
levels of activity. This finding is further supported by our
longitudinal finding that the stable moderate and always
active groups had similar mortality risks. Our results there-
fore provide additional data supporting the call by the 2008
Physical Activity Guidelines for Americans for Sedentary
Older Adults With Chronic Diseases and Disabilities to be
as physically active as abilities and conditions allow (28).
In addition, our study demonstrates that the ability to main-
tain an active or moderately active lifestyle was associated
with the lowest mortality rate, which is consistent with our
hypothesis that stability in activity level is a marker of
greater physiologic reserve. The observation of increased
mortality associated with fast decliners after adjustment for
baseline activity status highlights the importance of moni-
toring changes in physical activity level over time.

Walking for exercise and indoor household chores were
the 2 activities most likely to change among older women.
Walking is known to be the most common physical activity
among physically active adults (29), and regular walking of
8 blocks a week is protective against further mobility loss
among disabled older women (30). Taken together, these
findings suggest that walking, as an inexpensive and
readily accessible form of exercise, may be a particularly
effective and attainable goal for promoting physical activity,
especially among functionally challenged older adults
with limited exercise capacity. A prior report indicated that
some disabled older women are able to maintain walking at
a level consistent with guideline recommendations, suggest-
ing greater potential for activity than is currently seen (31).

Despite the persuasive evidence of health benefits of
regular physical activity and exercise, most older adults
are not physically active enough to achieve these benefits.
Consistent with previous reports (32, 33), we found that
obesity, self-reported fair or poor health, mobility disabil-
ity, low self-efficacy, and having a greater number of dis-
edases (coronary artery disease and COPD in particular) and
depressive symptoms are strongly associated with both in-
activity at baseline (results not shown) and a tendency to
maintain a sedentary lifestyle. These findings provide guide-
ance for factors to mitigate or prevent to help maintain
physical activity.

The strengths of our study include longitudinal data, the
community-based representative sample, the inclusion of
initially high-functioning women, which allowed for better
delineation of temporal relations, and latent variable model-
ing that took into account measurement error and missing
data. In addition, we implemented a novel statistical ap-
proach to aid the selection of a subjective measure of phys-
cal activity for the study. The observed heterogeneity in
different measures was striking and has not been addressed
previously. By choosing a measure that minimized the
degree of uncertainty associated with intraperson transitions
in physical activity status, we not only achieved objectivity
but also optimized our ability to identify meaningful trajec-
tory patterns. The reason that the NHIS criteria out-
performed the CDC/ACSM criteria could be 2-fold. First,
the former accounts for not only duration and frequency
but also intensity of activities. Second, the CDC/ACSM
definition of inactivity as no activity at all may not repre-
sent the usual level of activity for older adults because in-
terruption of activity participation for short period of time
may be more frequent among older adults compared with
younger adults because of older adults’ increased vulnera-
bility to acute health problems or weather related factors.

Despite these strengths, several limitations should be con-
sidered when interpreting our results. First, our analyses were
restricted to high-functioning older women living in the com-
munity. Therefore, the results cannot be generalized to older
men or to more disabled women. Second, questionnaire-
based assessments of physical activity may be subject to
recall bias (34–36). However, using subjective measures for
ranking rather than quantifying physical activity levels
among older adults may still be valid (37). The observed
dose-response relation between activity trajectory and mor-
tality in our study supports the utility of the self-report.
Third, only 6 of the original 18 activities in the Minnesota
Leisure Time Activities Questionnaire were assessed in the
WHAS, which may lead to underestimation of the between-person heterogeneity in physical activity level.
However, the WHAS subset has been shown to be an effec-
tive surrogate for the full Minnesota Leisure Time Activities Questionnaire in older women with high predictive accura-
cy and validity (38). Fourth, the identification of predictors
of change in physical activity level was restricted to base-
line covariates. Few studies have investigated the impact of
change in risk factors on change in physical activity in older adults. More longitudinal work that accounts for time-varying risk factors is needed to improve our ability to delineate temporal relations with the ultimate goal of identifying causes of sedentary behavior and fast decline in physical activity. Finally, given that increasing illness and disability over time could be both risk factors for and consequences of sedentary behavior or decline in physical activity through negative feedback mechanisms, the observed association between decline in physical activity and mortality may be partially explained by the increased burden of illness and disability. Further work is needed to assess the degree of mediating and feedback effects such that the health benefits of physical activity intervention can be better quantified.

In summary, our findings have several practical implications for promoting physical activity in older women. First, physical activity does not have to be vigorous and time-consuming to be beneficial, but a moderate activity level should be maintained. Second, given that most of the decline in physical activity in older women was due to a decrease in walking and doing household chores rather than regular exercise, programs tailored to overcome individual (and perhaps environmental) barriers to the walking may yield the most benefits. Third, by delineating the impact of individual-level demographic, psychosocial, and health characteristics on physical activity engagement in older women, our study informs the development of future screening and intervention efforts to target older women who might benefit the most, namely those with chronic diseases such as obesity, coronary artery disease, or COPD, depressive symptoms, low self-efficacy, mobility disability, and low energy level.

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Author affiliations: Department of Medicine, Division of Geriatric Medicine and Gerontology, School of Medicine, Johns Hopkins University, Baltimore, Maryland (Qian-Li Xue, Ravi Varadhan, Wenliang Yao); Center on Aging and Health, Johns Hopkins Medical Institutions, Baltimore, Maryland (Qian-Li Xue, Karen Bandeen-Roche, Sarah L. Szanton, Roland J. Thorpe, Rita R. Kalyani, Ravi Varadhan, Wenliang Yao); Department of Biostatistics, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland (Karen Bandeen-Roche); Department of Epidemiology, Mailman School of Public Health, Columbia University, New York, New York (Thelma J. Mielenz, Linda P. Fried); Department of Community and Preventive Medicine, School of Medicine and Dentistry, University of Rochester, Rochester, New York (Christopher L. Seplaki); Department of Health Systems and Outcomes, School of Nursing, Johns Hopkins University, Baltimore, Maryland (Sarah L. Szanton); Department of Health Policy and Management, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland (Roland J. Thorpe); Johns Hopkins Center for Health Disparities Solutions, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland (Roland J. Thorpe); Department of Medicine Division of Endocrinology and Metabolism, School of Medicine, Johns Hopkins University, Baltimore, Maryland (Rita R. Kalyani); Benjamin Leon, Jr., Family Center for Geriatric Research and Education and Department of Medicine, Herbert Wertheim College of Medicine, Florida International University, Miami, Florida (Paulo H. M. Chaves); Department of Medicine, College of Physicians and Surgeons, Columbia University, New York, New York (Thuy-Tien L. Dam); Department of Medicine, Mount Sinai School of Medicine, New York, New York (Katherine Ornstein); and Department of Biostatistics, Mailman School of Public Health, Columbia University, New York, New York (Arindam RoyChoudhury).

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REFERENCES


