Research Article

Association of Physical Activity History With Physical Function and Mortality in Old Age

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Abstract

Background. We examined whether physical activity in early adulthood, late midlife, and old age as well as cumulative physical activity history are associated with changes in physical functioning and mortality in old age.

Methods. Data are from participants aged 65 years or older enrolled in the InCHIANTI study who were followed up from 1998–2000 to 2007–2008 (n = 1,149). At baseline, participants recalled their physical activity levels at ages 20–40, 40–60, and in the previous year, and they were categorized as physically inactive, moderately active, and physically active. Physical performance was assessed with the Short Physical Performance Battery and self-reported mobility disability was evaluated at the 3-, 6- and 9-year follow-up. Mortality follow-up was assessed until the end of 2010.

Results. Physical inactivity at baseline was associated with greater decline in Short Physical Performance Battery score (mean 9-year change: −2.72, 95% CI: −3.08, −2.35 vs −0.98, 95% CI: −1.57, −0.39) and greater rate of incident mobility disability (hazard ratio 4.66, 95% CI 1.14–19.07) and mortality (hazard ratio 2.18, 95% CI 1.01–4.70) compared to physically active participants at baseline. Being physically active throughout adulthood was associated with smaller decline in physical performance as well as with lower risk of incident mobility disability and premature death compared with those who had been less active during their adult life.

Conclusions. Higher cumulative physical activity over the life course was associated with less decline in physical performance and reduced rate of incident mobility disability and mortality in older ages.

Key Words: Physical activity—Physical performance—Disability—Mortality

Physical activity is one of the key components of a healthy lifestyle (1). Moderate-to-vigorous physical activity is associated with reduced risk of several chronic diseases including cardiovascular disease, stroke, type 2 diabetes, breast and colon cancer, osteoporosis, and depression (2,3). Regular physical activity also relates to better physical and cognitive functioning in old age and longevity (4–6).

The majority of previous studies examining the association between physical (in)activity with health outcomes in old age are based on a single measurement of physical activity either earlier in life or at older ages. However, level of physical activity can vary across the life span depending on individual, sociocultural, and environmental factors (7,8). Based on few previous studies that have taken into account physical activity at different stages of life, physical activity across adulthood seems to have cumulative benefits on physical performance in midlife and old age (9–11). However, to our knowledge, no previous studies have combined physical activity history data with repeated measures of physical performance and self-reported functioning or with mortality follow-up.
Using data from the InCHIANTI study, the present study investigated whether physical activity at different stages of life as well as cumulative physical (in)activity was associated with the decline in physical performance, risk of incident mobility disability, and mortality.

Methods

Study Design and Participants

Data are from participants aged 65 years or older enrolled in the InCHIANTI study (Invecchiare in Chianti, aging in the Chianti area). The baseline data were collected in 1998-2000 and the participants were thereafter followed up 3-year intervals in 2001-2003, 2004-2006, and 2007-2008. The design of the study and data collection methods have been described in detail elsewhere (12). Out of the random sample of 1,260 persons, 1,155 agreed to participate in the study and 1,149 responded to the physical activity history questions at baseline.

Participants received an extensive description of the study and participated after providing written informed consent. The Italian National Institute of Research and Care on Aging Ethical Committee approved the study protocol, which complied with the principles stated in the Declaration of Helsinki.

Physical Activity Measurements

Physical activity was assessed through an interviewer-administered questionnaire. At baseline, participants were asked to indicate their average level of physical activity during the past year and at two age periods in life: 20–40 years and 40–60 years. The response categories were (1) minimal physical activity (2), light physical activity: performed 2–4 hours per week not accompanied by sweating (3), moderate physical activity: performed 1 to 2 hours per week accompanied by sweating or light physical activity not accompanied by sweating for more than 4 hours per week (4), moderate physical activity: performed ≥3 hours per week accompanied by sweating, and (5) physical exercise: performed regularly that required maximal strength and endurance several times per week.

Consistent with a previous InCHIANTI Study investigation (12), the five categories of physical activity were collapsed into three levels in order to obtain stable estimates of effect and to approximate recommended levels of physical activity by the U.S. Department of Health and Human Services: (i) physically inactive combining the first two categories reflecting insufficient physical activity, (ii) moderate activity defined by the third category, and (iii) physical activity combining the last two categories, exceeding Department of Health and Human Services recommendations (3). The Department of Health and Human Services recommendations for adults are to engage in either moderate-intensity physical activity for ≥30 minutes on ≥5 days per week or vigorous-intensity physical activity on ≥3 days per week for ≥20 minutes per occasion (3).

To evaluate physical activity history, cumulative physical activity score was calculated as Cooper and colleagues have proposed (10). At each of the three time points (20–40 years, 40–60 years, and baseline) those who were classified as inactive were assigned a value of 0; those as moderately active, a value of 1; and those as physically active, a value of 2. The scores from each age were then summed to create a cumulative physical activity score ranging from 0 (inactive at all three ages) to 6 (meeting physical activity recommendations at all three ages). For the analyses we grouped participants into four groups: 0, 1–2, 3–4, and 5–6.

Physical Function Outcomes

Physical performance was evaluated with the Short Physical Performance Battery (SPPB), which consists of 4-m walking speed test at usual pace, 5 time chair rise test, and standing balance test (13). All the tests were carried out using identical methods at all study phases (12). Each physical performance measure was categorized into a 5-level score, with 0 representing inability to do the test and 4 representing the highest level of performance. Both the walking and chair rise tasks were each scored from 1 to 4 based on quartile cut-points from normative data on community-dwelling older adults (14). The three measures were then added to create a summary physical performance measure ranging from 0 (worst) to 12 (best). The SPPB has been shown to have excellent 1-week test–retest reliability (intraclass correlation 0.88–0.92) (15) and to predict nursing home admission, disability, and mortality (14,16). Total of 996 participants had baseline SPPB measurement and were included in the SPPB analyses.

As a part of the interview, participants were asked whether they had any difficulties in walking 400 m or climbing a flight of stairs with the response options being (i) no difficulty, (ii) with difficulty but without help, (iii) with some help from another person, and (iv) unable to perform the activity. Mobility-related disability was defined as need for help or inability to walk 400 m or to climb a flight of stairs (16). Self-reported mobility disability predicts future disability, nursing home admission, and mortality (13,17). After excluding participants with mobility disability at baseline (n = 140), 1,009 participants were included in the analysis concerning mobility disability outcome.

Mortality Outcome

Information on vital status during the follow-up was gathered from the Mortality General Registry maintained by the Tuscany Region and the death certificates deposited at the Registry Office of the municipality of residence. In this study, mortality that occurred between 1998, the year of enrollment, and the end of 2010 was considered.

Covariates

Covariates for the analysis were derived from the baseline. Education was recorded in years. Body mass index was calculated as measured weight in kilograms divided by measured height in meters squared (kg/m2). Smoking status was categorized into never smokers, former smokers, and current smokers. Daily alcohol (g) intake was estimated by the European Prospective Investigation into Cancer and Nutrition Food Frequency Questionnaire (18) and persons were classified as ≥30g/day vs <30g/day.

Diseases were ascertained by a trained geriatrician according to standard, pre-established criteria and algorithms combining information from self-reported physician diagnoses, current pharmacological treatment, medical records, clinical examinations, and blood tests (19). The following diseases were considered: coronary heart disease, stroke, peripheral arterial disease, diabetes, asthma, chronic bronchitis, knee and hip osteoarthritis, and cancer). Depressive symptoms were evaluated with the Center for Epidemiologic Studies Depression Scale (20,21) and a score ≥16 was considered to indicate present depressive symptoms. To reduce the number of covariates we combined some of the disease states (bronchitis and asthma into pulmonary disease and knee and hip osteoarthritis into lower extremity osteoarthritis). Sensitivity analysis was performed and the main results remained unchanged when models were controlled for a larger set of covariates.
Statistical Analysis
Characteristics of the study population at baseline are reported by sex as mean values for continuous variables and percentages for categorical variables. To examine 9-year change in physical performance according to the baseline physical activity, we utilized generalized estimation equations using an exchangeable correlation structure to control for the intra-individual correlation between repeated measurements (22,23). In addition, we examined the role of past physical activity at ages 40–60 and 20–40 by hierarchically adjusting the models for these variables and their interaction with time. Models were adjusted for age, sex, education, lifestyle factors, and chronic diseases. The role of baseline and physical activity history in the 9-year incidence of mobility disability was examined with a Cox proportional hazards model. Person-time for each participant was calculated from the date of the baseline examination to the date of the first self-reported mobility disability, date of death, or date of the last study contact, whichever came first. Finally, we performed separate analysis for 10-year mortality with Cox proportional hazards model. Cox models were also hierarchically adjusted for past physical activity, lifestyle factors, and chronic diseases.

To investigate 9-year change in physical performance, 9-year incidence of mobility disability and 10-year mortality according to the cumulative physical activity score, we used generalized estimation equations and Cox proportional hazards model, respectively. Models were hierarchically adjusted for age, sex, education, lifestyle factors, and chronic diseases. To examine whether baseline and physical activity history was differently associated with physical performance decline and incidence of mobility disability and mortality in men and women, interactions with sex were tested. None of the interaction terms were statistically significant (all \( p > .10 \)), thus men and women were combined together in the analyses.

Finally, we compared participants who were excluded due to missing data on physical activity or physical performance at baseline \( (n = 155) \) to those who were included in the SPPB analysis \( (n = 996) \). All statistical analyses were performed using the SAS 9.4 Statistical Package (SAS Institute Inc., Cary, NC).

**Results**

Baseline characteristics of the study population are shown in Table 1. Study population was younger \((74.8 \pm 79.6 \text{ years})\), more educated \((5.3 \text{ vs } 4.9 \text{ years})\), and they had less chronic conditions than participants who were excluded due to missing data on physical activity or physical performance at baseline \((n = 155)\).

Table 2 shows the average 9-year change in SPPB score, incidence of mobility disability, and mortality according to the physical activity level at baseline. Compared with active participants, persons who were inactive at baseline showed greater decline in SPPB score and greater hazards for mobility disability and mortality. Adjustment for previous physical activity did not affect the differences between baseline physical activity groups in terms of SPPB decline but attenuated the group differences for mobility disability and mortality outcomes and even more so after adjustment for baseline lifestyle factors and chronic diseases. Results regarding physical activity at ages 20–40 and 40–60 are shown in Supplementary Table 1. Physical inactivity at ages 20–40 and 40–60 was associated with greater SPPB decline and greater hazard of incident mobility disability compared with those who were physically active after adjustment for baseline physical activity, lifestyle factors, and diseases. Physical activity at ages 20–40 and 40–60 did not associate with risk of premature death.

Table 3 shows the average 9-year change in SPPB score, incidence of mobility disability, and mortality according to the cumulative physical activity score. An association between cumulative physical activity score with decline in the SPPB score was observed; those who had mostly been active showed smallest decline in SPPB score. Visual representation of the SPPB score results is shown in Supplementary Figure 1. Cumulative physical activity score was also strongly associated with incident mobility disability and premature death. Compared with those participants who had mostly been active during their adult life, those participants who had been inactive throughout their adult life had higher hazards for incident mobility disability (OR 4.91, 95% CI 2.27–10.63) and for death (hazard ratio 2.04,
### Table 2. Mean 9-Year Change in Short Physical Performance Battery Score and the 9-Year Hazards of Mobility Disability and the 10-Year Hazards of Mortality According to Physical Activity Level at Baseline

<table>
<thead>
<tr>
<th>SPPB(^{†})</th>
<th>n</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β*</td>
<td>95% CI</td>
<td>β</td>
<td>95% CI</td>
<td>β</td>
</tr>
<tr>
<td>Active</td>
<td>-0.98</td>
<td>-1.57, -0.39</td>
<td>-0.68</td>
<td>-1.36, -0.01</td>
<td>-0.38</td>
</tr>
<tr>
<td>Moderate</td>
<td>-1.74</td>
<td>-2.12, -1.36</td>
<td>-1.32</td>
<td>-1.75, -0.90</td>
<td>-1.01</td>
</tr>
<tr>
<td>Inactive</td>
<td>-2.72</td>
<td>-3.08, -2.35</td>
<td>-2.74</td>
<td>-3.14, -2.33</td>
<td>-2.36</td>
</tr>
<tr>
<td>Mobility disability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>2.28</td>
<td>0.54, 9.54</td>
<td>1.96</td>
<td>0.46, 8.34</td>
<td>1.90</td>
</tr>
<tr>
<td>Moderate</td>
<td>4.66</td>
<td>1.14, 19.07</td>
<td>3.80</td>
<td>0.91, 15.83</td>
<td>3.47</td>
</tr>
<tr>
<td>Inactive</td>
<td>1.47</td>
<td>0.67, 3.20</td>
<td>1.39</td>
<td>0.63, 3.07</td>
<td>1.34</td>
</tr>
</tbody>
</table>

Notes: CI = confidence interval; HR = hazard ratio; SPPB = Short Physical Performance Battery; Model 1: adjusted for age, sex, and education; Model 2: Model 1 + adjusted for physical activity at ages 40–60 and at 20–40; Model 3: Model 2 + adjusted for smoking, BMI, and alcohol consumption; Model 4: Model 3 + adjusted for coronary heart disease, stroke, peripheral arterial disease, diabetes, lung disease, knee or hip osteoarthritis, depressive symptoms, and cancer.

\(\beta\) Estimate describes the 9-year change in SPPB score.

\(n\) Nine-year follow-up.

\(n\) Ten-year follow-up.

### Table 3. Mean 9-Year Change in Short Physical Performance Battery Score and the 9-Year Hazards of Mobility Disability and the 10-Year Hazards of Mortality According to Cumulative Physical Activity Score

<table>
<thead>
<tr>
<th>SPPB(^{†})</th>
<th>n</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β*</td>
<td>95% CI</td>
<td>β</td>
<td>95% CI</td>
</tr>
<tr>
<td>5–6 (most of the time active)</td>
<td>-1.61</td>
<td>-2.07, -1.14</td>
<td>-2.10</td>
<td>-3.54, -0.66</td>
</tr>
<tr>
<td>3–4</td>
<td>-2.32</td>
<td>-2.74, -1.90</td>
<td>-2.77</td>
<td>-4.23, -1.32</td>
</tr>
<tr>
<td>1–2</td>
<td>-2.66</td>
<td>-3.17, -2.15</td>
<td>-2.88</td>
<td>-4.35, -1.42</td>
</tr>
<tr>
<td>0 (inactive at all three ages)</td>
<td>-1.89</td>
<td>-2.57, -1.22</td>
<td>-2.45</td>
<td>-3.89, -1.00</td>
</tr>
<tr>
<td>Mobility disability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5–6 (most of the time active)</td>
<td>1.24</td>
<td>0.96, 1.50</td>
<td>1.86</td>
<td>1.57, 2.15</td>
</tr>
<tr>
<td>3–4</td>
<td>1.74</td>
<td>1.44, 2.05</td>
<td>2.15</td>
<td>1.83, 2.48</td>
</tr>
<tr>
<td>1–2</td>
<td>3.74</td>
<td>1.88, 7.40</td>
<td>3.78</td>
<td>1.99, 7.28</td>
</tr>
<tr>
<td>0 (inactive at all three ages)</td>
<td>3.91</td>
<td>2.27, 5.63</td>
<td>4.32</td>
<td>2.60, 5.55</td>
</tr>
</tbody>
</table>

Notes: CI = confidence interval; HR = hazard ratio; SPPB = Short Physical Performance Battery; Model 1: adjusted for age, sex, and education; Model 2: Model 1 + adjusted for smoking, BMI, and alcohol consumption; Model 3: Model 2 + adjusted for coronary heart disease, stroke, peripheral arterial disease, diabetes, lung disease, knee or hip osteoarthritis, depressive symptoms, and cancer.

\(\beta\) Estimate describes the 9-year change in SPPB score.

\(n\) Nine-year follow-up.

\(n\) Ten-year follow-up.

95% CI 1.24–3.35). After adjusting for lifestyle factors and chronic diseases the results remained statistically significant.

### Discussion

Using data from a 9-year follow-up study of community-dwelling older adults, we found that engagement in physical activity throughout adulthood, that is, cumulative physical activity, was associated with smaller decline in physical performance as well as with reduced rate of incident mobility disability and premature death compared to those who had been less active during their adult life.

The results of the current study are convergent with previous studies showing the benefits of cumulative lifetime physical activity on physical functioning in old age (9,10). Our study extends previous observations by examining the long-term decline in physical functioning (both objective and self-reported) as well as examining the association between physical activity history and mortality. We also examined separately the role of physical activity at different periods in time to understand whether there are sensitive periods when physical activity is mostly advantageous for later life health and functioning. The results of these analyses suggest that, independent of physical activity in old age, physical inactivity at ages...
20–40 and 40–60 was associated with greater physical performance decline and greater hazard of incident mobility disability, but not with mortality. Only cumulative physical inactivity was significantly associated with mortality risk. The results confirm our hypothesis that physical activity earlier in life may influence subsequent decline in physical functioning. However, due to the limited sample size and multicollinearity between past and current physical activity, it is difficult to disentangle the effect of current and past physical activity on functional decline.

Physical activity across the life course may relate to physical function in a number of ways. First, the direct effects of physical activity (depending on the type of activity) include improved muscle strength, aerobic fitness, flexibility, and balance. All these factors are closely associated with physical performance and functioning (24), and low muscle strength and aerobic fitness have shown to predict premature death (25–27). Second, physical activity is known to be protective against various diseases, such as type 2 diabetes, coronary heart disease, stroke, and cancer (1–3, 28), whose consequences include reduced functioning and premature death. Third, regular physical activity provides psychological benefits in relation to cognitive functions, depressive symptoms, and improved feelings of self-control and self-efficacy (29–31). These beneficial effects may help older persons to stay active, participate in the community, and thus maintain also physical functioning. Strengths of this study include retrospective questions about physical activity at ages 20–40 and 40–60 years allowing us to examine the role of physical activity history. An additional strength compared to other studies in this field is a follow-up with repeated measures of both objectively measured physical performance and self-reported mobility disability. This enabled us to examine changes in physical function decline from a wide perspective. The present study also has some limitations. First, excluding persons with missing data on physical activity history or physical performance at baseline resulted in relatively younger and healthier sample. Thus it is likely that the observed rate of physical function decline is underestimated, especially in the inactive group. Second, information on physical activity history was based on the retrospective ascertainment of prior physical activity levels and validity of these questions has not been tested. Moreover, the relatively simple physical activity questionnaire did not allow detailed examination of type, intensity, and duration of physical activity at different stages of adulthood. Future studies should confirm our findings by utilizing longitudinal data with repeated measurement of physical activity preferably based on objective measurements.

In conclusion, engagement in physical activity throughout adulthood is associated with reduced physical performance decline as well as lower rate for mobility problems and premature death in old age. Thus, promoting physical activity across the life course is important to help to maintain physical functioning into old age.

**Supplementary Material**

Supplementary material can be found at: [http://biomedgerontology.oxfordjournals.org/](http://biomedgerontology.oxfordjournals.org/)

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**References**


