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Physical Activity and Years of Healthy Life in Older Adults: Results From the Cardiovascular Health Study

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Abstract

Little is known about how many years of life and disability-free years seniors can gain through exercise. Using data from the Cardiovascular Health Study, the authors estimated the extra years of life and self-reported healthy life (over 11 years) and years without impairment in activities of daily living (over 6 years) associated with quintiles of physical activity (PA) in older adults from different age groups. They estimated PA from the Minnesota Leisure Time Activities Questionnaire. Multivariable linear regression adjusted for health-related covariates. The relative gains in survival and years of healthy life (YHL) generally were proportionate to the amount of PA, greater among those 75+, and higher in men. Compared with being sedentary, the most active men 75+ had 1.49 more YHL (95% CI: 0.79, 2.19), and the most active women 75+ had 1.06 more YHL (95% CI: 0.44, 1.68). Seniors over age 74 experience the largest relative gains in survival and healthy life from physical activity.

Keywords

aging; exercise; mortality; health status; activities of daily living

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The 2008 *Physical Activity Guidelines for Americans* (U.S. Department of Health and Human Services, 2008) recommend that older adults engage in at least 150 min of moderate-intensity, or 75 min of vigorous, aerobic physical activity per week. The guidelines also recommend muscle-strengthening exercises involving all major muscle groups 2 or more days per week. Recognizing that older adults are a medically and functionally diverse population, the guidelines urge seniors to be as physically active as permitted by their medical conditions and impairments, even if they cannot attain the recommended intensity, duration, and frequency of exercise.

Epidemiologic studies have demonstrated a lower risk of mortality among older adults who are physically active than in those who are sedentary (Aijo, Heikkinen, Schroll, & Steen, 2002; Bijnen et al., 1999; Fried et al., 1991; Gregg et al., 2003; Hirvensalo, Rantanen, & Heikkinen, 2000; Landi et al., 2004; Manini et al., 2006; Miller, Rejeski, Reboussin, Ten Have, & Ettinger, 2000; Rakowski & Mor, 1992; Sherman, D'Agostino, Cobb, & Kannel, 1994a; Stessman, Maaravi, Hammerman-Rozenberg, & Cohen, 2000). This reduction in mortality risk appears remarkably stable over time, persisting for 16 years among women in the Framingham Heart Study cohort and 22 years among male participants in the Harvard Alumni Health Study (Lee, Hsieh, & Paffenbarger, 1995; Lee & Paffenbarger, 2000; Sherman, D'Agostino, Cobb, & Kannel, 1994b). Although the studies differ in the ways they assessed physical activity and defined a physically active lifestyle, overall they demonstrate that older individuals need to be active but can perform less vigorous physical activity than middle-aged adults to achieve a significant reduction in mortality risk. Regular physical activity also has been associated with lower rates of functional decline (Berk, Hubert, & Fries, 2006; Boyle, Buchman, Wilson, Bienias, & Bennett, 2007; Christensen, Stovring, Schultz-Larsen, Schroll, & Avlund, 2006; Ferrucci et al., 1999; Hirvensalo et al., 2000; Leveille, Guralnik, Ferrucci, & Langlois, 1999; Miller et al., 2000; Mor et al., 1989; Patel et al., 2006; Schroll, Avlund, & Davidsen, 1997; Tager, Haight, Sternfeld, Yu, & van Der Laan, 2004; Wang, Ramey, Schettler, Hubert, & Fries, 2002).

However, few studies have provided the actual number of years of extra life or years free of disability that can be gained from a physically active lifestyle. Using data from the Framingham Heart Study, Franco et al. (2005) calculated mean life expectancy after age 50 from the hazard ratio for mortality, stratifying by level of physical activity. Moderately active men and women lived 1.3 and 1.1 more years than sedentary individuals, respectively, whereas high levels of physical activity led to gains of 3.7 and 3.5 years. In population-based samples of people age 65 and older, moderate to high physical activity contributed to greater estimated active life expectancies than low physical activity (Ferrucci et al., 1999). In addition, little is known about the comparative benefits of physical activity, compared with being sedentary, for measured survival and years free of impairment in older adults from different age groups. The objectives of this study were twofold: in older adults from different age groups, to compare survival and years of self-reported healthy life associated with different levels of physical activity over 11 years of follow-up and to compare the number of years free from activities-of-daily-living (ADL) disability associated with physical activity over 6 years of follow-up.

Methods

Study Cohort

The Cardiovascular Health Study (CHS) is an ongoing, observational, population-based cohort study of people age 65 and over recruited from four communities in the United States: Sacramento County, CA; Allegheny County, PA; Forsyth County, NC; and Washington County, MD. The CHS supplemented the original cohort of 5,201 men and women, which was enrolled between 1989 and 1990, with an additional 687 African

Americans during the fourth study year (1992–1993). Details of the study design are described elsewhere (Fried et al., 1991; Tell et al., 1993).

Data Collection

Using standardized questionnaires and procedures, trained technicians collected demographic and psychosocial information, data on health habits, a standardized medical history for selected conditions and current medications, objective cardiovascular data, reported and objective measures of physical performance, data on affective state and cognitive functioning, and blood samples for a variety of laboratory analyses performed at the Laboratory for Clinical Biochemistry Research at the University of Vermont. Participants returned for annual clinic visits and underwent telephone interviews 6 months after each visit through 1999. Limited telephone surveillance for study outcomes has continued since 2000. Deaths initially were identified by interview with an informant and listings in obituary columns and later confirmed by reviewing medical records, death certificates, and the HCFA health-care-utilization database for hospitalizations. There has been 100% ascertainment of participant mortality.

Variables

Outcome Variables—The three outcomes of interest were years of life (YOL; the number of years that a participant lived in the 11 years after baseline), years of healthy life (YHL; the number of years during which a participant reported being in good to excellent health [vs. fair or poor health or dead] in the following 11 years), and the number of years that a participant had no ADL difficulties in the 6 years after baseline (YHL-ADL). Impairment in ADL was defined as any reported difficulty walking around the home, getting out of bed, eating, dressing, bathing, or using the toilet. YHL was calculated as the weighted sum of the 12 available measures of self-reported health, with the first and last weighted by one half to correspond with the trapezoidal approximation of the area under the curve. YHL-ADL was calculated in a similar way.

Predictor Variable—The principal predictor variable was the energy in kilocalories expended in weekly household and leisure-time physical activity estimated from the Minnesota Leisure Time Activities Questionnaire (MLTAQ; Taylor et al., 1978). For 16 activities (e.g., moderately strenuous household chores, gardening, walking for exercise, dancing, golf), the MLTAQ algorithmically translated the frequency and average duration of the activities into an estimated weekly energy expenditure in kilocalories. The MLTAQ, developed for the Multiple Risk Factor Intervention Trial, has proven test–retest reliability (Spearman’s rank correlation coefficient .79–.88; Folsom, Jacobs, Caspersen, Gomez-Marín, & Knudsen, 1986), predicts cardiovascular and all-cause mortality in middle-aged men (Leon & Connett, 1991), and correlates reasonably well with measured energy expenditure but may underestimate actual activity in older men and women (Albanes, Conway, Taylor, Moe, & Judd, 1990; Starling, Matthews, Ades, & Poehlman, 1999). In the CHS, kilocalorie estimates were based on participant self-report of activities for the 2 weeks before the baseline visit.

Analytic Approach

These analyses include both the original and the African American cohorts. Because we sought to estimate the mean number of additional years that participants were alive, reported good to excellent health, or were free of ADL impairment, compared with their sedentary counterparts, we used multivariable least-squares regression to assess the independent contribution of baseline physical activity to each of the outcome measures. Although the three outcome measures were somewhat skewed, the central-limit theorem guarantees that

regression coefficients will be normally distributed if the sample size is large enough (Lumley, Diehr, Emerson, & Chen, 2002). We performed preliminary regression analyses using robust standard errors or bootstrap standard errors and found that results were virtually identical. For this reason, we used ordinary least squares throughout. We chose to analyze years of life in this way, rather than perform survival analysis, because all participants were followed for the same length of time. For purposes of clarity, we chose to analyze all three outcome measures in the same manner.

Participants were stratified into three age groups: 65–69, 70–74, and 75. Physical activity in kilocalories was divided into age-category-specific quintiles, with participants in the lowest quintile serving as the reference group. To test for interactions between gender and exercise, we combined men and women in a multivariate model into which we entered activity categories (in quintiles), baseline age, baseline ADL and instrumental ADL, and all the possible interactions between male gender and the exercise categories. The effect of activity on YOL, YHL, and YHL-ADL was significantly higher for men than for women in the highest activity group. For this reason, we also stratified participants by gender.

For each outcome, separate regressions were run for the three age groups. As potential confounders, we selected variables that previously had been shown to predict 5-year mortality in the CHS (Fried et al., 1998). We also selected variables that had a bivariate association with, or which plausibly could contribute to, ADL impairment. Covariates were separated into the following categories: demographic characteristics, baseline physical functioning, health habits, adjudicated prevalent cardiovascular disease (CVD), risk factors for CVD, subclinical CVD (e.g., ankle-brachial index, internal carotid-wall thickness), comorbid conditions, inflammatory markers, and cognition and depression (see the Appendix). Habitual physical activity before the age of 65 was measured at study entry on a 5-point Likert scale with the question, “Prior to age 65, describe the level of physical activity compared to others your same age and sex.” We assessed cognitive function with the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). Because the CHS switched to the 100-item Modified MMSE (Teng & Chui, 1987) after the first year, we converted the modified MMSE back into a 30-point scale to allow the merging of data from the original and African American cohorts. We measured depressive symptoms by a 10-item version of the Center for Epidemiological Studies depression questionnaire (CES-D; Orme, Reis, & Herz, 1986). Values for fixed-effect covariates (e.g., race) were obtained at study entry. Values for all other covariates corresponded to the 1992–1993 study year (the analytic baseline for this study).

Longitudinal data were collected on each outcome variable for all eligible participants for all years. Data that were missing between the first and last known measurements were imputed from a person-specific regression of the variable on the log of time from the last known measure. For outcome measurements that were missing from the last year of data collection, we imputed values using the last observation carried forward until death (Engels & Diehr, 2003). Overall, the amount of missing outcome data was low because of excellent follow-up. Less than 6% of data for self-reported health were missing, and 8% were missing for ADL. The valid *N* for individual predictor variables ranged from 5,729 to 5,868; participants with missing data for any of the covariates were excluded. Consequently, regressions with the chief predictor, kilocalories, plus all selected covariates yielded models with a valid *N* of 5,386. We compared the covariate data for the excluded cases with those that were retained for the analyses. There were only two significant differences: People who were dropped for missing data were more likely to have congestive heart failure and lower scores on the MMSE.

We developed three models for each outcome. The first model included only the principal predictor, kilocalories of weekly physical activity. In Model II we added demographic characteristics plus, for YHL and YHL-ADL, the baseline scores for self-reported health and ADL, respectively. In the fully adjusted model (Model III), we included the variables of Model II plus an extensive array of health-related variables (Appendix). For Models II and III, we entered both age and the natural logarithm of age to allow the outcomes to be a nonlinear function of age.

We formally tested for differences in the effect of exercise between men and women, between age groups, and by initial health status. We created a simpler model using tertiles of physical activity to ensure sufficient numbers in the various groups. We based the activity tertiles on the entire sample, so that they were the same for each age-gender group. The model included age group, gender, activity tertile, baseline self-reported health (good to excellent vs. fair to poor), and baseline ADL status (no impairment vs. some impairment). All possible interaction terms for age group, activity level, and gender with each other and with the other covariates were entered by forward selection.

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 13 (SPSS, Inc., Chicago, IL) and Stata version 9.2 (Stata-Corp, College Station, TX).

Results

Table 1 shows the baseline characteristics of the study cohort by gender and quintile of physical activity. Within the cohort as a whole (not shown in Table 1), participants with the highest levels of physical activity were on average slightly younger than the least active, more likely to be male and White, and more likely to have had postsecondary-school education. Compared with the lowest activity quintile, the most active men and women reported better overall health and fewer depressive symptoms and were less likely to have hypertension, diabetes, obstructive lung disease, or coronary heart disease. The most active men, but not the most active women, had a lower prevalence of arthritis than their sedentary peers. Not surprisingly, the most physically active participants also reported less baseline functional impairment than their sedentary peers. The amount of baseline leisure-time and chore-related physical activity ranged from a low of 0 kcal/week to over 13,000 kcal/week, regardless of age group. The mean weekly energy expenditure was consistently lower in women than in men. As shown in Table 2, the mean energy expended in physical activity declined within each energy quintile with successively older age groups. For the highest activity quintile, the percent reduction in energy expenditure from one age group to the next was less than for the lowest activity quintile. As a result, the most active seniors age 75 and older exercised nearly as much as the most active individuals age 65–69.

Survival in the 11 years after study entry averaged 9.96 ($\pm$ 2.34) years for participants age 65–69 and 8.10 ($\pm$ 3.30) years for those age 75 and older (numbers in parentheses are standard deviations). Of the participants, 60.9% lived the full 11 years. Over 11 years of follow-up, years with reported good to excellent health averaged 2.21–2.67 years less than mean survival, depending on age group, but only 17.6% of the entire sample reported good to excellent health for all 11 years. Fifty-two percent of participants reported a full 6 years without any ADL difficulty, with older participants, on average, having fewer impairment-free years than younger participants. Table 3 summarizes observed survival and years of healthy life (over 11 years of follow-up) and observed years without ADL impairment (over 6 years of follow-up), stratified by gender and baseline level of physical activity.

Regression coefficients, which represent the additional number of years of life in each quintile compared with Quintile 1, are shown in Table 4. The outcome measures were generally associated with physical activity in the hypothesized direction (Table 4, Model I). Adjusting for age, education, race (Black vs. non-Black), and the baseline value of the outcome measure slightly weakened the associations (Model II). Controlling for health-related covariates, some of which may have been in the causal pathway between exercise and the outcomes, further reduced the added years of life, healthy life, and years free of impairment that could be attributed to physical activity (Model III). Compared with their sedentary peers, the most physically active participants in the oldest age group generally showed the greatest relative gains in years of life, years of healthy life, and years free of impairment.

Among those age 75 and older, a consistent monotonic relationship between activity level and years gained was seen among men but was absent for YOL among women. Men in the highest quintile of physical activity, before adjustment, showed nearly twice the relative gain in YOL as the most physically active women (2.12 years [95% CI 1.38, 2.86] vs. 1.19 years [95% CI 0.55, 1.83]; Table 4A). The gain in years, compared with the least active quintile, shrank after adjustment for demographics and health-related covariates, remaining statistically significant for men but losing significance for women. After adjustment for covariates, the top activity quintiles of the oldest age group for men and women, plus the highest quintile for men age 70–74, showed an increase in YHL attributable to physical activity relative to the least active quintile (Table 4B). In the oldest age group, the relative gain in YHL (over the next 11 years) increased monotonically with increasing level of activity. The most active men in all three age groups, but only the most active women in the over-74 age group, showed a small but significant increase in YHL-ADL (over the next 6 years), compared with the least active quintile (0.35–0.57 year in men, 0.38–0.65 year in women; Table 4C). Because the extra years associated with physical activity are conditional on the time of observation, the magnitude of effect on YHL-ADL cannot be compared directly with the magnitude of effect on YOL or YHL. Our test for interactions among gender, age, and physical activity (not shown here), using activity tertiles that were based on the entire sample, revealed that men in the highest tertile had significantly more YOL, YHL, and YHL-ADL than expected from a model without interaction terms (an additional 0.56 year [95% CI 0.26, 0.86; $p < .001$], 0.60 year [95% CI 0.27, 0.92; $p < .001$], and 0.18 year [95% CI 0.2, 0.34; $p = .028$], respectively). Participants age 75 and older in the highest activity tertile also had significantly more YOL, YHL, and YHL-ADL than others (0.53 year [95% CI 0.20, 0.86; $p = .001$], 0.42 year [95% CI 0.06, 0.77; $p = .019$], and 0.28 year [95% CI 0.10, 0.46; $p = .002$], respectively). Potential interactions between activity and baseline self-reported health and between activity and baseline ADL were not significant, indicating that the effect of physical activity was similar whether the individual reported good or poor health or reported ADL independence or impairment. There was no significant three-way interaction among age, gender, and activity level.

Discussion

Based on the fully adjusted models, our study suggests that the survival advantage associated with physical activity in people over age 65 accrues primarily to men of advanced old age (75+) who expend at least 1,800 kcal/week in physical activity (corresponding to the lower confidence limit of the mean kilocalorie expenditure for men age 75+ in the fourth quintile of activity). The lack of association between physical activity and survival in the young-old may reflect, in part, their low overall mortality rate. Although performing moderate to intense physical activity in advanced old age could be construed as a marker of robust health leading to greater survival, our adjustment for an extensive array of personal and health characteristics argues against such an explanation. Manini et al. (2006) assessed

energy expenditure in high-functioning community-dwelling adults over age 69 and followed them for an average of 6.2 years. Active energy expenditure between 521 and 770 kcal/day (measured by doubly labeled water) was associated with a 35% lower mortality risk than in individuals with an active energy expenditure <521 kcal/day. An active energy expenditure of 521–770 kcal/day corresponded to an average of 1,204 kcal/wk derived from self-reported physical activity. By contrast, analysis of data from the Study of Osteoporotic Fractures (7,553 women, mean age 76.9) revealed a lower threshold of 163–503 kcal/week to achieve a significant reduction in mortality. The study also did not find a clear dose-response effect on mortality-risk reduction with increasing activity quintiles (Gregg et al., 2003). The comparatively higher threshold of energy expenditure required for survival benefit in our analysis (and lack of a significant benefit in women) may have been the consequence of extensive adjustment for health-related covariates not available in the other studies. The use of different methodologies to assess physical activity also may have contributed to the difference in thresholds.

Although reported exercise behavior before age 65 was not associated with any study outcomes in our multivariable models, we did not have information on exercise for the years immediately before enrollment for participants older than 65 at study entry. Consequently, we were unable to determine whether the survival benefit of physical activity was driven by a long-term, cumulative effect on health or by a more near-term effect. In the Study of Osteoporotic Fractures, 7,553 women underwent two assessments approximately 6 years apart and were followed for an additional 6.7 years. Gregg et al. (2003) found that staying or becoming active was associated with similar reductions in the hazard rate ratios for all-cause and cardiovascular mortality, after adjusting for age, smoking, body-mass index, self-reported health, and a variety of comorbidities. Conversely, becoming sedentary was equivalent to remaining sedentary in conferring an increased risk of dying (Gregg et al., 2003). Although restricted to women, the results suggest that current, not past, physical activity in old age confers survival benefit and that this survival benefit attenuates over the span of a few years once an individual becomes inactive. However, Gregg et al.'s results may have been influenced by selection bias, in that those who changed their level of exercise may have done so because of their health. By contrast, our analysis, as well as results for women (but not men) from the Framingham Study, have shown that a single assessment of physical activity in people age 75 and older can predict a lower risk of mortality as far out as 10–11 years (Sherman et al., 1994a). A limitation in interpreting our findings and those of other epidemiological studies of exercise and mortality in the elderly is the lack of information on how variability of exercise behavior after activity assessment may have influenced the effect of exercise on mortality.

A notable finding of our study was the manner in which the effect of baseline physical activity on the number of years with reported good to excellent health closely paralleled the effect on actual survival. Poor self-rated health has been shown to be a robust predictor of mortality in older adults, even after adjustment for comorbidities (Bosworth et al., 1999). In turn, physical activity has been shown to correlate significantly with self-reported health in middle-aged and older adults, as well as in people with chronic illness and disability (Cott, Gignac, & Badley, 1999; Kanagae et al., 2006; Wolinsky, Stump, & Clark, 1995). Using logistic regression, Leinonen, Heikkinen, and Jylha (2001) observed that a decline in physical activity, but not baseline physical activity, predicted a decrease in self-reported health over 5 years in a Finnish cohort of 75-year-old men and women. More research is required to explore the interrelationships between physical activity and other known determinants of self-rated health.

We have previously shown in the CHS cohort that weekly physical activity expressed in kilocalories independently correlates with gait speed and the time to complete five chair

stands (Hirsch et al., 1997), measures that are directly related to quadriceps strength (Brown, Sinacore, & Host, 1995; Ploutz-Snyder, Manini, Ploutz-Snyder, & Wolf, 2002). Although muscle strength declines with age, it may remain above the threshold for an effect on physical performance among sedentary young-old adults. With advancing age, this threshold has a greater likelihood of being crossed (Ploutz-Snyder et al., 2002), enabling the relative benefits of a physically active versus sedentary lifestyle for the prevention of disability to become manifest.

In our models for YOL and YHL (Tables 4A and 4B), the addition of demographic variables and the baseline values of the outcome variable (Model II) attenuated the significant independent contribution of physical activity to these outcomes in the oldest age group. The addition of an extensive array of health-related covariates to the models (Model III) further attenuated—but did not eliminate—the independent contribution of physical activity. Controlling for these health-related variables may have led to an overadjustment and consequent underestimation of the effect of exercise, because characteristics such as body-mass index and CVD may lie in the causal pathway between exercise and the respective outcomes.

As with survival, we could not determine whether the protective effect of baseline physical activity on impairment-free years occurred as a result of cumulative physical activity throughout old age or the effect was more proximal. Christensen et al. (2006) analyzed the impact of inactivity on mortality among 387 survivors of the Glastrup (Denmark) 1914 age cohort. After adjustment for gender, smoking, and household composition, physical inactivity at age 70 predicted disability at age 75, whereas cumulative physical activity between ages 50 and 70 did not.

Compared with being sedentary, higher levels of physical activity contributed more years of life to men than it did to women, after controlling for baseline demographic and health characteristics. These differences may have been the result of the higher average kilocalorie expenditure in men in all age groups and quintiles of physical activity. Alternatively, because women have a greater life expectancy than men, their expected survival during the 11 years of follow-up was longer and potentially less affected by their level of exercise. In the fully adjusted model (Table 4), women age 70–74 in the fourth activity quintile paradoxically lost half a year of life compared with sedentary women. Because no other result for women reached statistical significance in this model, the result likely represents a chance finding rather than evidence of harm caused by physical activity. A limitation of performing as many regressions as we did is the increased risk of statistically significant, but false, associations (Type 1 error). In the over-74 age group, women in the third and fourth activity quintiles had significantly higher relative gains in YHL-ADL than the corresponding men (Table 4C). This difference may partially reflect the greater susceptibility of women than men to disability as they enter advanced old age (Jagger et al., 2007), as well as the ability of exercise to delay it.

Conclusions

In cross-sectional analysis, mean leisure-time energy expenditure declines in successively older age groups. A single measurement of physical activity predicts added years of life and years with self-reported good to excellent health up to 11 years later, as well as years free of disability up to 6 years later, relative to being sedentary. After adjustment for demographic and health characteristics, the extra survival and years of self-reported healthy life associated with leisure-time physical activity (compared with being sedentary) are proportionate to the amount of physical activity, are greatest among those age 75 and older, and are generally higher in men than in women but remain modest even at the highest weekly energy

expenditures. Relative to sedentary older adults, seniors who are physically active also have more impairment-free years for ADL. As with years of life and healthy life, the relative gain in impairment-free years is highest in the oldest age group, and the absolute gain in disability-free years is small, even for the most active seniors.

Although the individual gains in years of life and healthy life may be modest, the public health implications are large. In the United States, the population age 75–79 is projected to grow to 5.3×10^6 men and 4.2×10^6 women by 2020 (U.S. Census Bureau, 2000). If they were active at the highest quintile of energy expenditure for their age group and gender, the men could gain up to 7.5×10^6 additional person-years of life over the ensuing 11 years (95% CI 3.8×10^6 , 11.3×10^6). (Based on our results, there would be no gain for the women.) This level of activity could add up to 3.0×10^6 person-years of ADL independence (over 6 years) for the men (95% CI 1.0×10^6 , 5.0×10^6), and the women could gain up to 1.6×10^6 person-years of ADL independence (over 6 years; 95% CI 0.7×10^6 , 3.0×10^6).

A strength of our study is that we found consistent results for the effect of physical activity on YOL and YHL whether we used activity levels that were specific for age group and gender or used activity levels that were defined for the sample as a whole. An additional strength of our study is that it refers to people in a general population (subject to their having enough baseline data). We also accounted for death, when looking at the other nonsurvival outcomes, by looking at the number of years in which there were favorable outcomes. However, although we controlled for an extensive array of health-related variables, physical activity may still be a marker for unmeasured good health. Because the CHS does not have accurate estimates of prebaseline physical activity, further research is required to determine whether taking up exercise in old age confers the same benefit for survival and disability-free years as having always been active.

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Appendix: Independent Variables Used in Linear Regressions

Category	Variable
Physical activity	Physical activity (kcal)
Demographic and personal characteristics	Gender Age Ln (age) Race (Black vs. non-Black) Education (years)
Baseline physical functioning	Activities of daily living Instrumental activities of daily living Difficulty climbing 10 steps Difficulty reaching, lifting, or grasping
Health habits	Smoking (current) Alcohol (drinks/week) Reported physical activity level before age 65
Adjudicated prevalent cardiovascular disease	Coronary heart disease Congestive heart failure Cerebrovascular disease (prior stroke, transient ischemic attack, or carotid endarterectomy)
Risk factors for cardiovascular disease	Diabetes mellitus Hypertension Hyperlipidemia (taking medication used to treat hyperlipidemia) Total cholesterol HDL cholesterol Regular aspirin use
Subclinical cardiovascular disease	Maximum average common carotid-wall thickness Maximum internal carotid intima-media thickness Internal carotid maximum % stenosis. Minimum ankle:arm ratio
Comorbid conditions	Self-reported arthritis Self-reported chronic obstructive pulmonary disease or asthma History of cancer Parkinson's disease (taking medication used to treat Parkinson's disease) Obesity (measured as body-mass index)
Inflammatory markers	C-reactive protein (mg/dl) Albumin (g/dl)
Cognition and affect	Mini-Mental State Exam score CES-D depression scale score

Baseline Characteristics of Study Population by Gender and Quintile of Household and Leisure-Time Physical Activity

Table 1

	Men's (<i>n</i> = 2,303) Quintile of Physical Activity					Women's (<i>n</i> = 3,083) Quintile of Physical Activity				
	Lowest	2	3	4	Highest	Lowest	2	3	4	Highest
<i>n</i>	442	478	455	463	465	591	613	618	633	628
Age										
<i>M</i>	73.5	73.3	73.0	73.1	73.1	72.5	72.5	72.3	72.3	72.2
<i>SD</i>	6.0	5.7	5.5	5.5	5.5	5.8	5.5	5.2	5.1	5.0
Black race										
<i>n</i>	86	89	63	41	32	158	129	90	67	57
%*	0.19	0.19	0.14	0.09	0.07	0.27	0.21	0.15	0.11	0.09
Education (years)										
<i>M</i>	13.7	13.7	14.0	14.4	14.7	13.1	13.2	13.8	13.9	13.5
<i>SD</i>	5.1	5.2	5.3	4.7	4.9	4.6	4.6	4.4	4.3	4.2
Good to excellent self-reported health										
<i>n</i>	294	340	363	380	390	358	436	487	511	506
%	0.67	0.71	0.80	0.82	0.84	0.61	0.71	0.79	0.81	0.81
Any ADL impairment										
<i>n</i>	42	24	22	20	16	110	59	48	32	30
%	0.10	0.05	0.05	0.04	0.03	0.19	0.10	0.08	0.05	0.05
Any IADL impairment										
<i>n</i>	144	110	79	61	40	300	205	160	138	112
%	0.33	0.23	0.17	0.13	0.09	0.51	0.33	0.26	0.22	0.18
Difficulty walking up 10 steps										
<i>n</i>	61	46	29	19	23	168	129	78	78	59
%	0.14	0.10	0.06	0.04	0.05	0.28	0.21	0.13	0.12	0.09
Difficulty reaching, lifting, or grasping										
<i>n</i>	105	74	64	59	52	298	238	184	187	187
%	0.24	0.15	0.14	0.13	0.11	0.50	0.39	0.30	0.30	0.30
Body-mass index										
<i>M</i>	26.9	26.7	26.4	26.2	26.0	28.3	27.1	26.6	26.3	25.9

	Men's (<i>n</i> = 2,303) Quintile of Physical Activity					Women's (<i>n</i> = 3,083) Quintile of Physical Activity				
	Lowest	2	3	4	Highest	Lowest	2	3	4	Highest
<i>SD</i>	4.0	3.7	3.9	3.7	3.4	6.3	5.3	4.9	4.6	4.5
Hypertensive or borderline hypertensive										
<i>n</i>	266	276	249	244	246	381	390	374	349	356
%	0.60	0.58	0.55	0.53	0.53	0.64	0.64	0.61	0.55	0.57
Current smoker										
<i>n</i>	55	64	44	43	39	84	89	69	77	73
%	0.12	0.13	0.10	0.09	0.08	0.14	0.15	0.11	0.12	0.12
Serum cholesterol (mg/dl)										
<i>M</i>	199.1	198.6	195.7	198.2	198.6	222.1	220.4	220.4	223.0	219.4
<i>SD</i>	38.0	37.7	34.1	33.3	35.7	40.1	38.6	39.9	36.8	38.2
Diabetes mellitus										
<i>n</i>	63	51	45	40	34	71	48	40	30	30
%	0.14	0.11	0.10	0.09	0.07	0.12	0.08	0.06	0.05	0.05
COPD or chronic asthma										
<i>n</i>	60	47	32	28	26	61	49	44	43	40
%	0.14	0.10	0.07	0.06	0.06	0.10	0.08	0.07	0.07	0.06
Arthritis										
<i>n</i>	220	190	193	209	204	355	355	337	353	355
%	0.50	0.40	0.42	0.45	0.44	0.60	0.58	0.55	0.56	0.57
Prevalent coronary heart disease										
<i>n</i>	128	123	101	123	102	118	101	90	84	71
%	0.29	0.26	0.22	0.27	0.22	0.20	0.16	0.15	0.13	0.11
Mini-Mental State Exam score ^d										
<i>M</i>	27.1	27.1	27.4	27.7	27.6	27.5	27.6	28.0	28.0	27.9
<i>SD</i>	3.1	3.2	2.9	2.4	2.6	2.7	2.8	2.2	2.1	2.3
CES-D score ^b										
<i>M</i>	4.7	4.2	4.0	3.4	3.2	6.5	5.3	4.9	4.7	4.5
<i>SD</i>	4.7	4.3	4.0	3.8	3.6	5.6	4.5	4.5	4.4	4.6

Note. The denominator for percentages is the total number of subjects within the quintile. ADL = activities of daily living; IADL = instrumental ADL; COPD = chronic obstructive pulmonary disease; CES-D = Center for Epidemiological Studies Depression questionnaire.

^aMaximum score = 30 (no cognitive impairment).

^bMaximum score = 10 (most depressed).

Table 2

Amount of Weekly Leisure-Time and Chore-Related Physical Activity in Kilocalories, Stratified by Age Group, Gender, and Quintile of Physical Activity

Quintile	Men			Women		
	Age group	M ± SD	Range	Age group	M ± SD	Range
1 (lowest)	65–69	149 ± 131	0–398	65–69	123 ± 114	0–330
	70–74	182 ± 147	0–446	70–74	57 ± 69	0–210
	75+	57 ± 77	0–248	75+	13 ± 27	0–90
2	65–69	675 ± 183	405–1,013	65–69	582 ± 153	330–848
	70–74	723 ± 161	450–1,020	70–74	451 ± 137	214–683
	75+	481 ± 143	263–735	75+	251 ± 95	98–405
3	65–69	1,411 ± 243	1,015–1,838	65–69	1,182 ± 201	851–1,558
	70–74	1,353 ± 202	1,031–1,740	70–74	985 ± 177	685–1,290
	75+	1,037 ± 178	743–1,364	75+	623 ± 122	410–853
4	65–69	2,627 ± 510	1,843–3,510	65–69	2,123 ± 379	1,560–2,875
	70–74	2,436 ± 454	1,755–3,293	70–74	1,885 ± 361	1,300–2,558
	75+	1,870 ± 360	1,368–2,625	75+	1,262 ± 260	855–1,740
5 (highest)	65–69	5,725 ± 2,122	3,518–1,3860	65–69	5,243 ± 2,365	2,885–14,625
	70–74	5,626 ± 2,198	3,315–1,3640	70–74	4,664 ± 2,061	2,565–13,039
	75+	4,805 ± 2,290	2,678–1,4228	75+	3,696 ± 2,252	1,743–1,4805

Table 3

Observed Years of Life, Years in Good to Excellent Health, and Years Without ADL Impairment by Gender and Baseline Level of Physical Activity

	Men's (<i>n</i> = 2,303) Quintile of Physical Activity					Women's (<i>n</i> = 3,083) Quintile of Physical Activity				
	Lowest	2	3	4	Highest	Lowest	2	3	4	Highest
<i>n</i>	442	478	455	463	465	591	613	618	633	628
Years of life (11 years of follow-up)										
<i>M</i>	7.78	8.13	8.69	9.03	9.39	9.11	9.57	9.76	9.79	9.97
<i>SD</i>	3.68	3.35	3.12	3.00	2.68	3.00	2.68	2.51	2.33	2.15
25th percentile	4.25	5.625	6.75	7.75	8.75	7.75	9.25	10.25	9.75	10.75
median	9.75	9.75	11	11	11	11	11	11	11	11
75th percentile	11	11	11	11	11	11	11	11	11	11
Years of life in good to excellent health (11 years of follow-up)										
<i>M</i>	5.06	5.81	6.52	7.13	7.63	5.64	6.73	7.34	7.43	7.71
<i>SD</i>	3.79	3.75	3.70	3.65	3.37	3.84	3.68	3.48	3.47	3.36
25th percentile	1.50	2.50	3.00	4.25	5.25	2.00	3.75	4.50	4.75	5.25
median	4.75	5.75	7.00	7.75	8.75	5.50	7.75	8.25	8.50	8.75
75th percentile	8.56	9.50	10.25	10.50	10.50	9.50	10.50	10.50	10.50	10.75
Years of life without any ADL impairment (6 years of follow-up)										
<i>M</i>	4.09	4.53	4.82	4.97	5.24	3.96	4.47	4.77	5.03	5.03
<i>SD</i>	2.12	1.86	1.73	1.61	1.40	2.15	1.90	1.67	1.57	1.54
25th percentile	2.50	3.50	4.00	4.50	5.00	2.00	3.50	3.88	4.50	4.50
median	5.00	5.50	6.00	6.00	6.00	4.50	5.50	6.00	6.00	6.00
75th percentile	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00

Note. ADL = activities of daily living.

Table 4A

Additional Years of Life ($N = 5,386$) Relative to the Least Active Quintile and Stratified by Gender and Age Group, Regression Coefficient (95% Confidence Interval)

Age group	Quintile	Men			Women		
		Model I	Model II	Model III	Model I	Model II	Model III
65-69	2	0.38 (-0.28, 1.04)	0.38 (-.28, 1.04)	-0.05 (-0.67, 0.57)	0.33 (-0.03, 0.69)	0.35 (-0.03, 0.73)	0.13 (-0.21, 0.47)
	3	0.41 (-0.25, 1.07)	0.35 (-0.31, 1.01)	-0.28 (-0.90, 0.34)	0.39 (0.03, 0.75)*	0.40 (0.02, 0.78)*	0.00 (-0.36, 0.36)
	4	1.11 (0.45, 1.77)***	1.02 (0.36, 1.68)**	0.25 (-0.39, 0.89)	0.33 (-0.03, 0.69)	0.45 (0.07, 0.83)*	-0.05 (-0.41, 0.31)
	5	0.94 (0.28, 1.60)**	0.86 (0.20, 1.52)**	0.01 (-0.63, 0.65)	0.51 (0.15, 0.87)**	0.52 (0.14, 0.90)**	0.00 (-0.38, 0.38)
70-74	2	0.54 (-0.14, 1.22)	0.47 (-0.21, 1.15)	-0.02 (-0.66, 0.62)	0.23 (-0.21, 0.67)	0.24 (-0.24, 0.72)	-0.17 (-0.61, 0.27)
	3	1.15 (0.47, 1.83)***	1.08 (0.40, 1.76)**	0.47 (-0.17, 1.11)	0.14 (-0.32, 0.60)	0.39 (-0.07, 0.85)	-0.3 (-0.76, 0.16)
	4	0.95 (0.25, 1.65)**	0.89 (0.19, 1.59)**	0.20 (-0.46, 0.86)	0.11 (-0.37, 0.59)	0.10 (-0.48, 0.58)	-0.54 (-1.00, -0.08)*
	5	1.70 (1.02, 2.38)***	1.59 (0.89, 2.29)***	0.81 (0.13, 1.49)*	0.71 (0.03, 1.19)**	0.61 (0.13, 1.09)**	0.08 (-0.40, 0.56)
75+	2	0.18 (-0.54, 0.90)	0.15 (-0.55, 0.85)	0.00 (-0.68, 0.68)	0.63 (0.07, 1.19)*	0.80 (0.18, 1.52)	0.34 (-0.18, 0.86)
	3	0.97 (0.21, 1.73)**	0.90 (0.18, 1.62)*	0.68 (0.06, 1.30)	1.22 (0.64, 1.80)***	1.03 (0.41, 1.65)***	0.64 (0.10, 1.18)
	4	1.62 (0.88, 2.36)***	1.37 (0.65, 2.09)***	1.07 (0.37, 1.77)**	1.18 (0.58, 1.78)***	1.35 (0.73, 1.97)***	0.69 (0.13, 1.25)
	5	2.12 (1.38, 2.86)***	1.82 (1.12, 2.52)***	1.42 (0.72, 2.12)***	1.19 (0.55, 1.83)***	1.35 (0.73, 1.97)***	0.66 (0.06, 1.26)

Note. Model I is unadjusted. Model II is adjusted for demographic variables: age and ln (age), race (Black vs. non-Black), and education (years). Model III is adjusted for all the variables listed in the Appendix. Quintile 5 is the most physically active; quintile 1 (reference group—not shown) is the least physically active.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 4B

Additional Years of Healthy Life ($N = 5,386$) Over 11 Years of Follow-Up Relative to the Least Active Quintile and Stratified by Gender and Age Group, Regression Coefficient (95% Confidence Interval)

Age group	Quintile	Men			Women		
		Model I	Model II	Model III	Model I	Model II	Model III
65–69	2	0.64 (–0.20, 1.48)	0.47 (–0.21, 1.15)	0.18 (–0.50, 0.86)	0.81 (0.21, 1.41)**	0.59 (0.05, 1.13)*	0.04 (–0.44, 0.52)
	3	1.25 (0.41, 2.09)**	0.44 (–0.26, 1.14)	0.10 (–0.58, 0.78)	1.42 (0.52, 2.04)***	0.67 (0.13, 1.41)*	0.15 (–0.35, 0.65)
	4	2.32 (1.48, 3.16)***	1.44 (0.76, 2.14)***	0.85 (0.17, 1.53)*	1.09 (0.47, 1.71)***	0.69 (0.15, 1.23)*	–0.15 (–0.67, 0.37)
	5	2.19 (1.53, 2.85)***	1.03 (0.33, 1.73)**	0.48 (–0.22, 1.18)	1.75 (1.13, 2.37)***	0.79 (0.25, 1.53)**	0.04 (–0.50, 0.58)
70–74	2	0.97 (0.13, 1.81)*	0.49 (–0.25, 1.23)	0.03 (–0.67, 0.73)	1.64 (0.98, 2.30)***	0.94 (0.34, 1.54)**	0.62 (0.10, 1.14)*
	3	1.76 (0.92, 2.60)***	0.86 (0.12, 1.60)*	0.48 (–0.22, 1.18)	1.60 (0.92, 2.28)***	1.09 (0.51, 1.67)***	0.19 (–0.35, 0.73)
	4	1.79 (0.95, 2.63)***	0.84 (0.10, 1.58)*	0.35 (–0.37, 1.07)	1.58 (0.90, 2.26)***	0.53 (0.20, 1.40)	–0.03 (–0.57, 0.51)
	5	2.66 (1.82, 3.50)***	1.57 (0.83, 2.31)***	0.99 (0.27, 1.71)**	1.72 (1.00, 2.44)***	0.80 (0.20, 1.40)**	0.27 (–0.29, 0.83)
75+	2	0.67 (–0.07, 1.11)	0.49 (–0.15, 1.13)	0.34 (–0.28, 0.96)	0.10 (–0.54, 0.74)	0.43 (–0.19, 1.05)	0.46 (–0.08, 1.00)
	3	1.19 (0.41, 1.97)**	0.64 (–0.04, 1.32)	0.50 (–0.16, 1.16)	1.87 (1.19, 2.55)***	0.93 (0.29, 1.57)**	0.57 (0.01, 1.13)*
	4	2.05 (1.29, 2.81)***	1.20 (0.54, 1.86)***	0.92 (0.28, 1.56)**	2.12 (1.42, 2.82)***	1.05 (0.41, 1.69)***	0.79 (0.19, 1.39)**
	5	2.81 (2.05, 3.57)***	1.91 (1.25, 2.57)***	1.49 (0.79, 2.19)***	2.20 (1.48, 2.92)***	1.31 (0.67, 1.95)***	1.06 (0.44, 1.68)***

Note. Model I is unadjusted. Model II is adjusted for demographic variables: age and ln (age), race (Black vs. non-Black), and education (years). Model also includes baseline self-reported health. Model III is adjusted for all the variables listed in the Appendix. Quintile 5 is the most physically active; quintile 1 (reference group—not shown) is the least physically active.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 4C

Years Free of ADL Impairment ($N = 5,386$) Over 6 Years of Follow-Up Relative to the Least Active Quintile and Stratified by Gender and Age Group, Regression Coefficient (95% Confidence Interval)

Age group	Quintile	Men			Women		
		Model I	Model II	Model III	Model I	Model II	Model III
65–69	2	0.42 (0.06, 0.78)*	0.42 (0.10, 0.74)**	0.26 (–0.04, 0.56)	0.28 (0.02, 0.54)*	0.04 (–0.18, 0.26)	0.42 (0.06, 0.78)*
	3	0.70 (0.34, 1.06)***	0.58 (0.26, 0.90)***	0.36 (0.04, 0.68)*	0.35 (0.09, 0.61)**	0.09 (–0.13, 0.31)	0.70 (0.34, 1.06)***
	4	0.71 (0.35, 1.07)***	0.54 (0.22, 0.86)***	0.13 (–0.13, 0.45)	0.52 (0.26, 0.78)***	0.11 (–0.13, 0.35)	0.71 (0.35, 1.07)***
	5	0.93 (0.57, 1.29)***	0.75 (0.43, 1.07)***	0.35 (0.03, 0.67)*	0.53 (0.27, 0.79)***	0.05 (–0.19, 0.29)	0.93 (0.57, 1.29)***
		0.67 (0.29, 1.05)***	0.51 (0.17, 0.85)**	0.30 (–0.02, 0.62)	0.36 (0.08, 0.66)*	0.19 (–0.07, 0.45)	0.67 (0.29, 1.05)***
70–74	2	0.85 (0.49, 1.21)***	0.67 (0.33, 1.01)***	0.34 (0.02, 0.66)*	0.72 (0.38, 1.06)***	0.06 (–0.22, 0.34)	0.85 (0.49, 1.21)***
	3	0.89 (0.51, 1.27)***	0.71 (0.37, 1.05)***	0.35 (0.01, 0.69)*	0.83 (0.49, 1.17)***	0.10 (–0.18, 0.38)	0.89 (0.51, 1.27)***
	4	1.12 (0.74, 1.50)***	0.92 (0.56, 1.28)***	0.49 (0.15, 0.83)**	0.62 (0.32, 0.92)***	0.16 (–0.14, 0.46)	1.12 (0.74, 1.50)***
	5	0.27 (–0.15, 0.69)	0.04 (–0.34, 0.42)	–0.16 (–0.52, 0.20)	0.03 (–0.33, 0.39)	0.15 (–0.15, 0.45)	0.27 (–0.15, 0.69)
		0.56 (0.12, 1.00)*	0.35 (–0.05, 0.75)	0.05 (–0.33, 0.43)	0.53 (0.17, 0.89)**	0.48 (0.18, 0.78)**	0.56 (0.12, 1.00)*
75+	2	1.00 (0.56, 1.44)***	0.66 (0.26, 0.75)***	0.35 (–0.03, 0.73)	0.88 (0.52, 1.24)***	0.65 (0.33, 0.97)***	1.00 (0.56, 1.44)***
	3	1.36 (0.94, 1.78)***	0.99 (0.61, 1.37)***	0.57 (0.19, 0.95)**	0.72 (0.36, 1.08)***	0.38 (0.04, 0.72)*	1.36 (0.94, 1.78)***
	4						
	5						

Note. ADL = activities of daily living. Model I is unadjusted. Model II is adjusted for demographic variables: age and ln (age), race (Black vs. non-Black), and education (years). Model also includes baseline ADL score. Model III is adjusted for all the variables listed in the Appendix. Quintile 5 is the most physically active; quintile 1 (reference group—not shown) is the least physically active.

* $p < .05$.

** $p < .01$.

*** $p < .001$.