

Physical Activity Recommendations and Decreased Risk of Mortality

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Background: Whether national physical activity recommendations are related to mortality benefit is incompletely understood.

Methods: We prospectively examined physical activity guidelines in relation to mortality among 252 925 women and men aged 50 to 71 years in the National Institutes of Health–American Association of Retired Persons (NIH-AARP) Diet and Health Study. Physical activity was assessed using 2 self-administered baseline questionnaires.

Results: During 1 265 347 person-years of follow-up, 7900 participants died. Compared with being inactive, achievement of activity levels that approximate the recommendations for moderate activity (at least 30 minutes on most days of the week) or vigorous exercise (at least 20 minutes 3 times per week) was associated with a 27% (relative risk [RR], 0.73; 95% confidence interval [CI], 0.68-0.78) and 32% (RR, 0.68; 95% CI, 0.64-0.73)

decreased mortality risk, respectively. Physical activity reflective of meeting both recommendations was related to substantially decreased mortality risk overall (RR, 0.50; 95% CI, 0.46-0.54) and in subgroups, including smokers (RR, 0.48; 95% CI, 0.44-0.53) and nonsmokers (RR, 0.54; 95% CI, 0.45-0.64), normal weight (RR, 0.45; 95% CI, 0.39-0.52) and overweight or obese individuals (RR, 0.48; 95% CI, 0.44-0.54), and those with 2 h/d (RR, 0.53; 95% CI, 0.44-0.63) and more than 2 h/d of television or video watching (RR, 0.50; 95% CI, 0.45-0.55). Engaging in physical activity at less than recommended levels was also related to reduced mortality risk (RR, 0.81; 95% CI, 0.76-0.86).

Conclusions: Following physical activity guidelines is associated with lower risk of death. Mortality benefit may also be achieved by engaging in less than recommended activity levels.

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PHYSICAL ACTIVITY PROMOTES health and longevity,^{1,2} and increasing participation in regular exercise has been a major public health goal in the United States for decades.³ The Office of the US Surgeon General (OSG), the Centers for Disease Control and Prevention (CDC), and the American College of Sports Medicine (ACSM) all endorse a minimum of 30 minutes of moderate activity on most days of the week, an amount and intensity of activity that is feasible for most Americans.^{4,5} Recent nationally representative survey data⁶ indicate that more than 50% of the adult US population do not meet the lower bound of the physical activity recommendations,^{4,5} a proportion that has remained essentially unchanged throughout the last decade.⁷ Commonly reported barriers to activity participation include lack of time and the perceived effort of exercise.⁸

Given the potential mortality benefit from achieving the physical activity guide-

lines, surprisingly little is known about current physical activity recommendations as they relate to mortality. The sparse epidemiologic data available suggest a 20% to 30% decreased mortality risk for subjects expending approximately 1000 kcal/wk—the equivalent of minimal adherence to the recommendations.⁹ Moreover, the specific role of activity of at least moderate intensity is poorly understood.¹⁰⁻¹² Several investigations found an inverse association only for vigorous activity¹³⁻¹⁸ or noted strong inverse relations with fitness,¹⁹⁻²¹ whereas other studies²²⁻²⁸ reported that moderate activity was also sufficient to decrease mortality risk.

We examined physical activity recommendations in relation to mortality in a large prospective cohort with comprehensive physical activity data. Our study differs from most previous investigations^{2,9} in quantifying the dose-response associations in a manner that facilitates an application to the current guidelines.^{4,5}

STUDY POPULATION

The National Institutes of Health–AARP (formerly known as the American Association of Retired Persons) (NIH–AARP) Diet and Health Study was established in 1995–1996, when 566 407 AARP members 50 to 71 years old who were residing in one of 6 US states (California, Florida, Louisiana, New Jersey, North Carolina, and Pennsylvania) or 2 metropolitan areas (Atlanta, Georgia, and Detroit, Michigan) responded to a baseline questionnaire requesting information on medical history, diet, and structured exercise.²⁹ Within 6 months of the baseline questionnaire, subjects were asked to complete a second questionnaire that collected additional exposure information, including lifestyle activity. Eligible subjects for the present study were participants who responded to both questionnaires and who were alive and had not moved out of the study area before returning the second questionnaire (n=334 905). Of these, we excluded individuals who reported a previous diagnosis of cancer (n=19 479), cardiovascular disease (n=45 621), or emphysema (n=8123) and individuals with missing information on physical activity (n=8757). After these exclusions, the analytic cohort comprised 252 925 subjects (142 828 men and 110 097 women). The study was approved by the Special Studies Institutional Review Board of the US National Cancer Institute. Completion of the self-administered baseline questionnaire was considered to imply informed consent.

COHORT FOLLOW-UP AND END POINT ASCERTAINMENT

Cohort members were followed up by annual linkage of the cohort to the National Change of Address database maintained by the US Postal Service, through processing undeliverable mail, by using other address change update services, and directly from cohort members' notifications. For matching purposes, we have virtually complete data on first and last name, address history, sex, and date of birth. Social security numbers are available for 85% of our cohort. Follow-up for vital status is performed by annual linkage of the cohort to the Social Security Administration Death Master File.³⁰ Verification of vital status and cause of death is provided by searches of the National Death Index (NDI) Plus.³¹ We estimate that follow-up for deaths in our cohort is more than 93% complete.^{30,31} Maintenance of the cohort also involves periodic linkage to the 8 state cancer registries serving our cohort.³² The primary end point in the present analysis was mortality from any cause. We also investigated the 2 main causes of death: mortality from cardiovascular disease (*International Classification of Diseases, Ninth Revision [ICD-9] codes 390.0–448.9*) and mortality from cancer (*ICD-9 codes 140.0–208.9*). In further analyses, we considered mortality from stroke and from a combination of cancers considered a priori to be associated with physical activity (ie, cancers of the colon, breast, prostate, lung, and endometrium).³³

ASSESSMENT OF PHYSICAL ACTIVITY

The baseline questionnaire inquired about structured vigorous exercise during the previous year, defined as the frequency each week spent at activities such as exercise and sports that lasted 20 minutes or more and caused either increases in breathing or heart rate or working up a sweat. There were 6 possible response options: never; rarely; 1 to 3 times per month; 1 to 2 times per week; 3 to 4 times per week; and 5 or more times per week. We used that assessment to examine the ACSM physical activity guidelines that recommend at least 20 min-

utes of continuous vigorous exercise 3 times per week³⁴ as a means of improving cardiorespiratory fitness.

The second questionnaire requested information on the average time spent each week at activities of at least moderate intensity using categories of never; rarely; weekly, but less than 1 h/wk; 1 to 3 h/wk; 4 to 7 h/wk; and more than 7 h/wk. Specific examples included brisk walking/fast dancing, walking during golf, hiking/mountain climbing, cheerleading/drill team, tennis, biking, swimming, aerobics, jogging/running, rowing, basketball/baseball, football/soccer, handball/racquetball, weight lifting, heavy gardening, and heavy housework. We used 3 hours of activity of at least moderate intensity per week as a cut point to approximate the current OSG/CDC/ACSM physical activity recommendations^{4,5} that emphasize the overall health benefits of 30 minutes of activity of moderate intensity on most days of the week.

Our physical activity assessment contains important elements of the Physical Activity Scale for the Elderly (PASE), which showed an intraclass correlation coefficient of 0.84 for 2 administrations of the questionnaire mailed 3 to 7 weeks apart³⁵ and a correlation coefficient of 0.58 comparing activity energy expenditure as assessed by the questionnaire with that using the doubly labeled water method.³⁶

STATISTICAL ANALYSIS

Cox proportional hazards regression³⁷ with age as the time scale was used to estimate relative risks (RRs) and 95% confidence intervals (CIs) of mortality. Follow-up time was calculated from the scan date of the second questionnaire until death from any cause or the end of study on December 31, 2001. Terms for activity of at least moderate intensity and vigorous exercise were entered into the models simultaneously to assess their independent effects. The models were adjusted for age, sex, race/ethnicity, marital status, family history of cancer, education, smoking status, menopausal hormone therapy, aspirin, and intakes of multivitamins, vegetables, fruit, red meat, and alcohol. Information on family history of cardiovascular disease was unavailable. Because body mass index (BMI) and smoking³⁸ could be intermediate steps in the causal pathways linking physical activity to decreased mortality, we analyzed the data with and without inclusion of those variables in the model.

RESULTS

During 1 265 347 person-years of follow-up, we documented 7900 deaths. At baseline, half of the cohort (50.4%) reported engaging in activity of at least moderate intensity for more than 3 h/wk, and slightly less than half (47.8%) reported engaging in a minimum of 20 minutes of vigorous exercise 3 times per week. Subjects with increased levels of activity of at least moderate intensity or vigorous exercise tended to have a higher education level and, as expected, were leaner, showed less adulthood weight gain, and had greater intakes of total energy compared with less active subjects (**Table 1**).

Increased physical activity was associated with a clear decrease in risk of mortality from any cause (**Table 2**). Compared with the lowest category of no activity of at least moderate intensity, participants in the highest category of more than 7 h/wk had a multivariate RR of 0.68 (95% CI, 0.63–0.74). For vigorous exercise, any level above the inactive category was related to decreased mortality risk. Compared with no vigorous exercise, the multivariate RR was 0.71 (95% CI, 0.66–0.77) for the highest cat-

Table 1. Baseline Characteristics According to Activity of at Least Moderate Intensity and Vigorous Exercise

Characteristic ^a	Activity of at Least Moderate Intensity, ^b h/wk					Vigorous Exercise, ^c Times per Week				
	Inactive	<1	1-3	4-7	>7	Inactive	<1	1-2	3-4	≥5
Participants, No.	34 426	26 685	64 289	65 717	61 808	40 856	34 843	56 233	70 282	50 711
Age, y	62.3	62.0	62.2	62.5	62.9	62.5	61.7	62.1	62.7	62.9
Sex, %										
Women	44	44	44	43	44	54	45	42	41	38
Men	56	56	56	57	56	56	55	58	59	62
Race/ethnicity, %										
White	91	92	94	94	94	92	94	94	94	94
Black	5	4	3	3	3	5	3	3	3	3
Hispanic	2	2	2	2	2	2	2	2	2	2
Asian/Pacific Islander/Native American	2	2	1	1	1	2	1	1	2	2
College education, %	70	76	78	79	76	66	75	78	80	79
Married or living as married, %	64	67	68	70	70	60	67	70	71	72
Family history of cancer, %	51	52	52	52	52	51	52	52	52	52
Current smoker, %	15	13	12	10	10	18	15	12	8	8
Past smoker, %	47	47	49	50	50	44	48	48	51	52
BMI	28.5	27.9	27.1	26.4	25.9	28.3	27.6	27.0	26.3	25.8
Weight gain since age 18 y, kg	21.1	19.8	17.7	15.5	13.9	20.8	19.2	17.7	15.4	13.3
Television or video watching, h/d	4	3	3	3	3	4	3	3	3	3
Current menopausal hormone therapy, % ^d	42	45	46	49	46	40	45	46	50	48
Past menopausal hormone therapy, % ^d	9	9	9	9	8	9	9	9	9	8
Regular aspirin use, % ^e	36	37	37	37	37	34	36	37	38	38
Total energy intake, kcal/d	1860	1809	1809	1829	1944	1835	1786	1838	1838	1960
Vegetable intake, servings/1000 kcal/d	1.6	1.7	1.8	1.9	1.9	1.6	1.7	1.8	1.9	2.0
Fruit intake, servings/1000 kcal/d	1.5	1.6	1.7	1.8	1.9	1.5	1.5	1.6	1.8	1.9
Red meat intake, g/1000 kcal/d	37	37	35	33	32	37	37	36	32	30
Alcohol intake, g/d	14	13	13	13	14	13	13	13	13	14
Multivitamin use, %	52	55	57	58	58	51	54	57	59	59

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

^aAll values (except age) were directly standardized to the age distribution of the cohort.

^bActivity of at least moderate intensity is defined as activities with an estimated energy expenditure of greater than 3 metabolic equivalents (METs). The MET is defined as the ratio of work to resting energy expenditure (1 MET = 1 kcal/kg/h or 3.5-mL oxygen uptake/kg/min). Resting energy expenditure is assumed to be 1 MET.

^cVigorous exercise is defined as activities that lasted 20 minutes or more and caused either increases in breathing or heart rate or working up a sweat.

^dAmong postmenopausal women.

^eRegular aspirin use is defined as use of aspirin or aspirin products once per week or more.

egory of at least 20 continuous minutes of vigorous exercise 5 or more times per week.

Adjustment for BMI had no appreciable effect on the risk estimates (Table 2). However, adjustment for smoking accounted for a considerable difference between the age- and sex-adjusted and multivariate findings for vigorous exercise. Inclusion of biological intermediary covariates that may mediate the effect of physical activity (hypertension, high cholesterol level, and diabetes) had no impact (data not shown).

To determine whether undiagnosed chronic disease may have caused a decrease in physical activity levels, thereby biasing our results, we excluded all deaths that occurred during the first 1, 2, and 3 years of follow-up and limited our analysis to subjects who reported undergoing regular cancer screening examinations at entry. Results were virtually unchanged (data not shown).

Much of the strong inverse association between physical activity and mortality was because of mortality from cardiovascular disease (Table 2). In contrast, physical activity was less strongly related to cancer mortality, but the decrease in risk was statistically significant. Compared with

the lowest category of no activity of at least moderate intensity, amounts of more than 7 h/wk were related to significantly decreased risk of cancer mortality (RR, 0.83; 95% CI, 0.74-0.93). Compared with no vigorous exercise, the multivariate RR of cancer mortality for at least 20 minutes of vigorous exercise 3 to 4 times per week was 0.82 (95% CI, 0.74-0.92), and 5 or more times per week of vigorous exercise provided no additional benefit.

We next investigated the effects of activity of at least moderate intensity at levels that approximate the OSG/CDC/ACSM consensus guidelines for moderate activity (30 minutes on most days of the week)^{4,5} and vigorous exercise as encouraged by the ACSM (20 minutes 3 or more times per week).³⁴ Activity levels reflective of meeting the recommendations of moderate activity and vigorous exercise both showed significant benefits for mortality (Table 3). Associations for mortality from cardiovascular disease were of comparable magnitude as those seen for mortality from any cause. Relations were weaker but evident for mortality from cancer.

We evaluated higher levels of physical activity by examining the effects of activity reflective of meeting both

Table 2. Relative Risk (RR) of Mortality From Any Cause and Mortality From Specific Causes According to Activity of at Least Moderate Intensity and Vigorous Exercise

Type of Activity ^a		Mortality From Any Cause				P Value for Trend	
Activity of at least moderate intensity, h/wk	Inactive	<1	1-3	4-7	>7		
	No. of deaths	1683	937	1940	1794	1546	
	Person-years	170 907	133 217	321 719	329 352	310 151	
	Age- and sex-adjusted RR (95% CI)	1 [Reference]	0.80 (0.74-0.87)	0.72 (0.68-0.77)	0.68 (0.63-0.73)	0.61 (0.57-0.66)	<.001
	Age- and sex-adjusted RR + BMI (95% CI)	1 [Reference]	0.81 (0.75-0.88)	0.74 (0.69-0.79)	0.70 (0.65-0.75)	0.63 (0.59-0.69)	<.001
	Age- and sex-adjusted RR + smoking (95% CI)	1 [Reference]	0.82 (0.75-0.89)	0.74 (0.70-0.80)	0.70 (0.65-0.75)	0.63 (0.59-0.68)	<.001
	Full multivariate RR (95% CI) ^b	1 [Reference]	0.85 (0.79-0.93)	0.79 (0.74-0.85)	0.76 (0.71-0.82)	0.68 (0.63-0.74)	<.001
Vigorous exercise, times per week	Inactive	<1	1-2	3-4	≥5		
	No. of deaths	2000	1109	1682	1775	1334	
	Person-years	202 815	174 174	281 371	352 635	254 352	
	Age- and sex-adjusted RR (95% CI)	1 [Reference]	0.70 (0.65-0.75)	0.66 (0.62-0.71)	0.55 (0.51-0.59)	0.58 (0.53-0.62)	<.001
	Age- and sex-adjusted RR + BMI (95% CI)	1 [Reference]	0.71 (0.66-0.77)	0.68 (0.63-0.73)	0.57 (0.53-0.61)	0.59 (0.52-0.64)	<.001
	Age- and sex-adjusted RR + smoking (95% CI)	1 [Reference]	0.72 (0.67-0.78)	0.71 (0.66-0.76)	0.61 (0.57-0.66)	0.65 (0.60-0.70)	<.001
	Full multivariate RR (95% CI) ^b	1 [Reference]	0.77 (0.71-0.83)	0.77 (0.72-0.82)	0.68 (0.63-0.73)	0.71 (0.66-0.77)	<.001
Activity of at least moderate intensity, h/wk	Inactive	<1	1-3	4-7	>7		
	No. of deaths	511	303	574	516	432	
	Age- and sex-adjusted RR (95% CI)	1 [Reference]	0.86 (0.75-1.00)	0.71 (0.63-0.81)	0.64 (0.56-0.73)	0.56 (0.49-0.65)	<.001
	Age- and sex-adjusted RR + BMI (95% CI)	1 [Reference]	0.88 (0.76-1.02)	0.74 (0.66-0.84)	0.68 (0.60-0.78)	0.60 (0.52-0.69)	<.001
	Age- and sex-adjusted RR + smoking (95% CI)	1 [Reference]	0.88 (0.76-1.02)	0.73 (0.65-0.83)	0.67 (0.58-0.76)	0.58 (0.50-0.67)	<.001
	Full multivariate RR (95% CI) ^b	1 [Reference]	0.94 (0.81-1.08)	0.80 (0.71-0.91)	0.75 (0.66-0.86)	0.65 (0.57-0.75)	<.001
	Vigorous exercise, times per week	Inactive	<1	1-2	3-4	≥5	
No. of deaths		611	316	491	521	397	
Age- and sex-adjusted RR (95% CI)		1 [Reference]	0.65 (0.56-0.74)	0.63 (0.56-0.71)	0.53 (0.47-0.60)	0.57 (0.50-0.65)	<.001
Age- and sex-adjusted RR + BMI (95% CI)		1 [Reference]	0.66 (0.58-0.76)	0.65 (0.58-0.74)	0.56 (0.50-0.64)	0.61 (0.53-0.70)	<.001
Age- and sex-adjusted RR + smoking (95% CI)		1 [Reference]	0.67 (0.58-0.77)	0.67 (0.59-0.76)	0.59 (0.52-0.67)	0.64 (0.56-0.74)	<.001
Full multivariate RR (95% CI) ^b		1 [Reference]	0.72 (0.63-0.82)	0.74 (0.66-0.84)	0.66 (0.59-0.76)	0.71 (0.62-0.82)	<.001
Activity of at least moderate intensity, h/wk		Inactive	<1	1-3	4-7	>7	
	No. of deaths	645	392	884	894	818	
	Age- and sex-adjusted RR (95% CI)	1 [Reference]	0.84 (0.74-0.95)	0.80 (0.72-0.89)	0.81 (0.72-0.90)	0.77 (0.68-0.86)	<.001
	Age- and sex-adjusted RR + BMI (95% CI)	1 [Reference]	0.84 (0.74-0.96)	0.81 (0.73-0.90)	0.82 (0.73-0.91)	0.79 (0.69-0.87)	.002
	Age- and sex-adjusted RR + smoking (95% CI)	1 [Reference]	0.86 (0.76-0.98)	0.83 (0.75-0.93)	0.84 (0.75-0.93)	0.79 (0.71-0.89)	.003
	Full multivariate RR (95% CI) ^b	1 [Reference]	0.88 (0.78-1.00)	0.86 (0.78-0.96)	0.88 (0.79-0.98)	0.83 (0.74-0.93)	.02
	Vigorous exercise, times per week	Inactive	<1	1-2	3-4	≥5	
No. of deaths		754	508	811	854	706	
Age- and sex-adjusted RR (95% CI)		1 [Reference]	0.84 (0.75-0.94)	0.82 (0.74-0.91)	0.66 (0.60-0.74)	0.75 (0.67-0.84)	<.001
Age- and sex-adjusted RR + BMI (95% CI)		1 [Reference]	0.85 (0.76-0.95)	0.83 (0.75-0.92)	0.67 (0.61-0.75)	0.76 (0.68-0.86)	<.001
Age- and sex-adjusted RR + smoking (95% CI)		1 [Reference]	0.87 (0.78-0.98)	0.89 (0.80-0.99)	0.76 (0.69-0.85)	0.88 (0.78-0.98)	.008
Full multivariate RR (95% CI) ^b		1 [Reference]	0.91 (0.81-1.02)	0.94 (0.85-1.04)	0.82 (0.74-0.92)	0.95 (0.85-1.07)	.23

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CI, confidence interval.

^a Activity of at least moderate intensity is defined as activities with an estimated energy expenditure of greater than 3 metabolic equivalents (METs). The MET is defined as the ratio of work to resting energy expenditure (1 MET=1 kcal/kg/h or 3.5-mL oxygen uptake/kg/min). Resting energy expenditure is assumed to be 1 MET. Vigorous exercise is defined as activities that lasted 20 minutes or more and caused either increases in breathing or heart rate or working up a sweat.

^b The multivariate models used age as the underlying time metric and included the following covariates: sex (women; men), body mass index (<18.5; 18.5-24.9; 25.0-29.9; 30.0-34.9; 35.0-39.9; and ≥40.0), smoking (never smoking; past smoking of 1-19 cigarettes per day; past smoking of ≥20 cigarettes per day; current smoking of 1-19 cigarettes per day; and current smoking of ≥20 cigarettes per day), race/ethnicity (white; black; Hispanic; and Asian/Pacific Islander/Native American combined), education (<high school; high school; vocational school or some college; and college graduate), marital status (married or living as married; and divorced, separated, widowed, or never married), family history of cancer (yes; no), menopausal hormone therapy (never; current or former user of estrogen only; current user of estrogen and progestin combined; former user of estrogen and progestin combined; and not applicable), aspirin use (yes; no), multivitamin use (yes; no), intakes of vegetables (quintiles), fruit (quintiles), red meat (quintiles), and alcohol (0; 0.01-4.9; 5.0-14.9; 15.0-29.9; 30.0-49.9; and ≥50.0 g/d). The multivariate analyses of activity of at least moderate intensity and vigorous exercise were mutually adjusted.

recommendations for moderate activity and vigorous exercise (**Table 4**). Compared with subjects who were physically inactive, those with activity levels equivalent to meeting both recommendations showed a strong reduction in risk for mortality from any cause (multivariate RR, 0.50; 95% CI, 0.46-0.54). A similarly strong inverse association was noted for mortality from

cardiovascular disease (multivariate RR, 0.48; 95% CI, 0.41-0.55) and mortality from stroke (multivariate RR, 0.40; 95% CI, 0.26-0.61), and a weaker relation was seen for mortality from cancer (multivariate RR, 0.74; 95% CI, 0.65-0.85) and mortality from physical activity-related cancers (multivariate RR, 0.73; 95% CI, 0.60-0.89). Those who reported doing some activity at less than recom-

Table 3. Relative Risk (RR) of Mortality From Any Cause and Mortality From Specific Causes According to Achievement of Physical Activity Recommendations

Variable	Recommendation for MPA ^a			Recommendation for VPA ^b		
	Inactive	No	Yes	Inactive	No	Yes
Mortality from any cause						
No. of deaths	1683	2877	3340	2000	2791	3109
Person-years	170 907	454 937	639 504	202 815	455 545	606 988
Age- and sex-adjusted RR (95% CI)	1 [Reference]	0.74 (0.70-0.79)	0.65 (0.61-0.69)	1 [Reference]	0.67 (0.63-0.71)	0.55 (0.52-0.59)
Full multivariate RR (95% CI) ^c	1 [Reference]	0.81 (0.76-0.86)	0.73 (0.68-0.78)	1 [Reference]	0.77 (0.72-0.81)	0.68 (0.64-0.73)
Mortality from cardiovascular disease						
No. of deaths	511	871	948	611	807	918
Age- and sex-adjusted RR (95% CI)	1 [Reference]	0.76 (0.68-0.85)	0.61 (0.54-0.69)	1 [Reference]	0.63 (0.57-0.70)	0.53 (0.48-0.60)
Full multivariate RR (95% CI) ^c	1 [Reference]	0.85 (0.75-0.95)	0.71 (0.63-0.80)	1 [Reference]	0.73 (0.66-0.82)	0.67 (0.60-0.75)
Mortality from cancer						
No. of deaths	645	1276	1712	754	1319	1560
Age- and sex-adjusted RR (95% CI)	1 [Reference]	0.81 (0.74-0.89)	0.79 (0.72-0.87)	1 [Reference]	0.82 (0.75-0.90)	0.69 (0.63-0.76)
Full multivariate RR (95% CI) ^c	1 [Reference]	0.87 (0.79-0.96)	0.87 (0.78-0.96)	1 [Reference]	0.92 (0.84-1.01)	0.87 (0.79-0.96)

Abbreviation: CI, confidence interval; MPA, moderate physical activity; VPA, vigorous physical activity.

^aRecommendation for MPA: more than 3 hours of activity per week of at least moderate intensity corresponding to 30 minutes of activity of moderate intensity on most days of the week.

^bRecommendation for VPA: 20 minutes of continuous vigorous exercise 3 or more times per week.

^cAdjusted for the covariates listed in a footnote in Table 2. The multivariate analyses of recommendation for MPA and recommendation for VPA were mutually adjusted.

Table 4. Relative Risk (RR) of Mortality From Any Cause and Mortality From Specific Causes According to Joint Categories of Physical Activity Recommendations

Variable	Inactive	Neither Recommendation	Recommendation for MPA Only ^a	Recommendation for VPA Only ^b	Recommendation for Both MPA and VPA
Mortality from any cause					
No. of deaths	879	2520	1392	1161	1948
Person-years	74 139	361 407	222 814	190 298	416 690
Age- and sex-adjusted RR (95% CI)	1 [Reference]	0.59 (0.55-0.64)	0.51 (0.47-0.56)	0.47 (0.43-0.51)	0.36 (0.33-0.39)
Full multivariate RR (95% CI) ^c	1 [Reference]	0.70 (0.65-0.75)	0.62 (0.57-0.68)	0.61 (0.55-0.66)	0.50 (0.46-0.54)
Mortality from cardiovascular disease					
No. of deaths	278	761	379	349	569
Age- and sex-adjusted RR (95% CI)	1 [Reference]	0.56 (0.49-0.65)	0.44 (0.38-0.51)	0.44 (0.37-0.51)	0.32 (0.28-0.37)
Full multivariate RR (95% CI) ^c	1 [Reference]	0.68 (0.59-0.78)	0.56 (0.48-0.65)	0.58 (0.49-0.68)	0.48 (0.41-0.55)
Mortality from cancer					
No. of deaths	308	1082	683	531	1029
Age- and sex-adjusted RR (95% CI)	1 [Reference]	0.73 (0.64-0.83)	0.72 (0.63-0.82)	0.62 (0.54-0.72)	0.55 (0.48-0.62)
Full multivariate RR (95% CI) ^c	1 [Reference]	0.83 (0.73-0.94)	0.83 (0.72-0.95)	0.79 (0.68-0.91)	0.74 (0.65-0.85)

Abbreviations: CI, confidence interval; MPA, moderate physical activity; VPA, vigorous physical activity.

^aRecommendation for MPA: more than 3 hours of activity of at least moderate intensity per week corresponding to 30 minutes of activity of moderate intensity on most days of the week.

^bRecommendation for VPA: 20 minutes of continuous vigorous exercise 3 times per week.

^cAdjusted for the covariates listed in a footnote in Table 2.

mended levels showed modest but significantly decreased risk of mortality from any cause, cardiovascular disease, and cancer.

Achievement of activity levels corresponding to the guidelines for either moderate activity or vigorous exercise or the combination of guidelines for moderate activity and vigorous exercise was inversely associated with mortality in subgroups defined by sex, age, race/ethnicity, education, smoking status, BMI, and television or video watching (**Table 5**), indicating no important effect modification (*P* value for interaction, >.05 for all). Vigorous exercise showed a particularly strong re-

duction in mortality risk among individuals with high (>2 h/d) television or video watching.

COMMENT

In this large prospective study, engaging in physical activity of at least moderate intensity for more than 3 h/wk was associated with a 27% decreased risk of mortality. Following the recommendation for vigorous exercise of 20 minutes 3 or more times per week was related to a 32% reduction in mortality risk. These data lend strong

Table 5. Multivariate Relative Risk of Mortality From Any Cause According to Joint Categories of Achievement of Recommendations for Activity of at Least Moderate Intensity and Vigorous Exercise in Subjects Defined by Selected Variables^a

Variable	No. of Deaths	Inactive	Neither Recommendation	Recommendation for MPA Only ^b	Recommendation for VPA Only ^c	Recommendation for Both MPA and VPA
Sex						
Women	2661	1 [Reference]	0.70 (0.61-0.79)	0.65 (0.57-0.75)	0.62 (0.53-0.73)	0.53 (0.46-0.61)
Men	5239	1 [Reference]	0.70 (0.64-0.77)	0.60 (0.54-0.67)	0.60 (0.54-0.69)	0.49 (0.44-0.54)
Age at baseline, y						
< 65	3454	1 [Reference]	0.69 (0.62-0.77)	0.64 (0.56-0.72)	0.60 (0.53-0.69)	0.50 (0.45-0.57)
≥ 65	4446	1 [Reference]	0.70 (0.63-0.78)	0.60 (0.54-0.68)	0.61 (0.54-0.68)	0.49 (0.44-0.55)
Race/ethnicity						
White	7409	1 [Reference]	0.70 (0.65-0.76)	0.62 (0.57-0.68)	0.62 (0.56-0.68)	0.51 (0.45-0.55)
Black	295	1 [Reference]	0.67 (0.47-0.96)	0.69 (0.46-1.05)	0.45 (0.29-0.68)	0.58 (0.39-0.86)
Hispanic	105	1 [Reference]	0.55 (0.30-0.99)	0.44 (0.22-0.88)	0.52 (0.26-1.03)	0.18 (0.09-0.39)
Asian/Pacific Islander/Native American	91	1 [Reference]	0.43 (0.22-0.85)	0.46 (0.22-0.96)	0.39 (0.19-0.82)	0.28 (0.14-0.57)
Education						
< High school	2371	1 [Reference]	0.69 (0.60-0.78)	0.61 (0.53-0.70)	0.53 (0.46-0.62)	0.48 (0.41-0.55)
College	5529	1 [Reference]	0.71 (0.64-0.78)	0.63 (0.57-0.71)	0.64 (0.57-0.72)	0.51 (0.46-0.57)
Current smoking status						
Smoker	6081	1 [Reference]	0.67 (0.61-0.73)	0.60 (0.54-0.66)	0.59 (0.53-0.65)	0.48 (0.44-0.53)
Nonsmoker	1819	1 [Reference]	0.74 (0.64-0.86)	0.64 (0.54-0.75)	0.63 (0.53-0.76)	0.54 (0.45-0.64)
BMI						
< 25	2876	1 [Reference]	0.68 (0.59-0.77)	0.58 (0.50-0.67)	0.58 (0.49-0.67)	0.45 (0.39-0.52)
≥ 25	5024	1 [Reference]	0.67 (0.61-0.74)	0.60 (0.54-0.66)	0.58 (0.52-0.65)	0.48 (0.44-0.54)
Television or video watching, h/d						
≤ 2	2154	1 [Reference]	0.71 (0.59-0.84)	0.59 (0.49-0.72)	0.67 (0.56-0.81)	0.53 (0.44-0.63)
> 2	5746	1 [Reference]	0.70 (0.64-0.77)	0.64 (0.58-0.70)	0.59 (0.53-0.65)	0.50 (0.45-0.55)

Abbreviations: BMI (calculated as weight in kilograms divided by height in meters squared); MPA, moderate physical activity; VPA, vigorous physical activity.

^aData are given as relative risk (95% confidence interval) unless otherwise specified. The multivariate models were adjusted for the covariates listed in a footnote in Table 2. In each case, the stratification variable was excluded from the model. Within each stratum, the category of inactive subjects served as the reference group.

^bRecommendation for MPA: more than 3 hours of activity of at least moderate intensity per week corresponding to 30 minutes of activity of moderate intensity on most days of the week.

^cRecommendation for VPA: 20 minutes of continuous vigorous exercise 3 or more times per week.

support to current physical activity guidelines, which endorse 30 minutes of moderate activity on most days of the week or 20 minutes of vigorous exercise 3 or more times per week.^{4,5,34}

Apart from the present study, only 1 previous investigation³⁹ has quantified both moderate and vigorous activity in a manner that facilitates a direct comparison with the physical activity guidelines. That modestly sized study from Germany³⁹ included 943 deaths and examined mortality from any cause and found a statistically significant inverse relation of recommended levels of activity of moderate activity to risk of mortality in women (RR, 0.65; 95% CI, 0.51-0.82) but not in men (RR, 0.90; 95% CI, 0.77-1.01). Conversely, vigorous activity at recommended levels was statistically significantly inversely related to mortality risk in men (RR, 0.74; 95% CI, 0.68-0.94) but not in women (RR, 0.78; 95% CI, 0.57-1.08).

Previous epidemiologic studies of physical activity and mortality generally presented data in study-specific categories that do not readily compare with the guidelines or provided estimates of energy expenditure that require conversion into units of time before they can be translated into levels that correspond to the guidelines.^{2,9} In those studies, an activity energy expenditure of approximately 1000 kcal/wk—an amount that corresponds to minimal adherence to the physical activity guidelines—was associated with a 20% to 30% reduction in mortality risk.^{16,18,40-43}

Our study has numerous important strengths, including the substantial cohort size yielding precise risk estimates, the uniform criteria for ascertaining deaths, and the evaluation of cause-specific mortality. Subjects with preexisting chronic disease were excluded at baseline, thereby reducing the potential influence of chronic disease on physical activity levels. In secondary analyses, we further minimized the potential for bias due to undiagnosed chronic disease by excluding the initial follow-up period and excluding subjects without regular screening examinations.

Inclusion of BMI and cardiovascular risk factors in the models had little impact on the physical activity and mortality relation, suggesting that regulation of these factors explains only a small portion of the benefit of physical activity. In contrast, adjustment for smoking had an appreciable impact on the association between vigorous exercise and cancer mortality, indicating the importance of considering both vigorous exercise and smoking levels in the assessment of cancer mortality risk.

Our study has certain limitations. Information on physical activity was self-reported, which invariably entails some degree of misclassification.⁴⁴ However, the large cohort size prohibited us from using more accurate measures, such as activity monitors.⁴⁵ In addition, validation studies comparing physical activity assessments similar to those used in this cohort with referent methods suggest that the reliability and validity of our instru-

ment is comparable to self-reported measures used in other cohorts.⁴⁶ Moreover, our activity measures were associated with current smoking, BMI, television or video watching, and total energy intake in the hypothesized directions, providing evidence of construct validity of our physical activity assessment. Using activity of at least moderate intensity to approximate the guidelines for moderate activity may have overstated the potential benefits of moderate activity because it includes vigorous activities. Likewise, our measure of vigorous exercise may have included some moderate activities, which would have understated the apparent protection afforded by vigorous exercise. We were unable to adjust for family history of cardiovascular disease, which may partly explain the stronger observed effects of physical activity on cardiovascular mortality than on cancer mortality.

Engaging in some activity at less than recommended levels provided protection from mortality. One potential explanation is overreporting of physical activity levels among active individuals. Notwithstanding, data from other studies^{14,22,26,28,47} suggesting that lower-than-recommended activity levels may suffice to achieve mortality benefits are intriguing and require further evaluation.

Our findings showing that vigorous exercise was associated with a striking reduction in mortality risk among individuals with high television or video watching indicates that vigorous activity has the greatest potential for health benefits among those who are physically inactive. That individuals with greater activity levels consumed more calories than their less active counterparts suggests that apart from dietary intake, being physically inactive represents an important determinant of positive energy balance.

Numerous governmental agencies and private organizations have made recommendations for the appropriate amount of physical activity. The OSG, the CDC, the ACSM, the Institute of Medicine of the National Academy of Sciences, and the joint US Department of Agriculture/Department of Health and Human Services Dietary Guidelines for Americans all endorse a minimum of 30 minutes of moderate activity on most days of the week for overall health benefits.^{4,5,48-50} In addition, several agencies and organizations have formulated complementary physical activity recommendations targeted at specific health goals such as weight control, cancer prevention, or cardiorespiratory fitness. Specifically, the Institute of Medicine recommends at least 60 minutes of moderate activity each day,⁴⁹ and the US Dietary Guidelines advocate 60 minutes of moderate to vigorous activity on most days of the week to prevent unhealthy adult weight gain.⁵⁰ The American Cancer Society calls for 45 to 60 minutes of moderate to vigorous activity on most days of the week to reduce the risk of developing obesity-related malignant conditions such as colon and breast cancers.⁵¹ The ACSM distinguishes between physical activity vs fitness and promotes vigorous activities for at least 20 minutes 3 times a week to improve cardiorespiratory fitness.³⁴ Thus, physical activity recommendations vary depending on the particular health issue of interest.

Mechanistic studies show that the beneficial effects of physical activity and fitness involve biological pro-

cesses that primarily mediate risk for cardiovascular disease and cancer.⁴ Many biological mechanisms are likely to operate both with moderate and vigorous activity levels.^{4,52} One study suggests that genetic factors do not account for physical activity-related mortality differences.⁵³ The independent nature of the association between physical activity and mortality that we observed following adjustment for and stratification by body mass index indicates that the metabolic pathways by which physical activity reduces mortality risk are not mediated through its impact on weight control. This suggests the value of regular exercise in promoting longevity not just for normal weight individuals but also for those who are overweight or obese.

In summary, engaging in more than 3 hours of at least moderate intensity activity per week decreases the risk of mortality by 27%. Substantial reduction in mortality risk can also be accomplished by 20 minutes of vigorous exercise 3 times per week. We conclude that following physical activity recommendations is associated with lower risk of death. In addition, our findings suggest that engaging in any physical activity by those who are currently sedentary represents an important opportunity to decrease the risk of mortality.

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