

Relationship of Walking to Mortality Among US Adults With Diabetes

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Background: Walking is associated with reduced diabetes incidence, but few studies have examined whether it reduces mortality among those who already have diabetes.

Objective: To estimate the association between walking and the risk for all-cause and cardiovascular disease (CVD) mortality among persons with diabetes.

Design: Prospective cohort study of a representative sample of the US population.

Setting: Interviewer-administered survey in the general community.

Participants: We sampled 2896 adults 18 years and older with diabetes as part of the 1990 and 1991 National Health Interview Survey.

Main Outcome Measure: All-cause and CVD mortality for 8 years.

Results: Compared with inactive individuals, those who walked at least 2 h/wk had a 39% lower all-cause mor-

tality rate (hazard rate ratio [HRR], 0.61; 95% confidence interval [CI], 0.48-0.78; 2.8% vs 4.4% per year) and a 34% lower CVD mortality rate (HRR, 0.66; 95% CI, 0.45-0.96; 1.4% vs 2.1% per year). We controlled for sex, age, race, body mass index (calculated as weight in kilograms divided by the square of height in meters), smoking, and comorbid conditions. The mortality rates were lowest for persons who walked 3 to 4 h/wk (all-cause mortality HRR, 0.46; 95% CI, 0.29-0.71; CVD mortality HRR, 0.47; 95% CI, 0.24-0.91) and for those who reported that their walking involved moderate increases in heart and breathing rates (all-cause mortality HRR, 0.57; 95% CI, 0.41-0.80; CVD mortality HRR, 0.69; 95% CI, 0.43-1.09). The protective association of physical activity was observed for persons of varying sex, age, race, body mass index, diabetes duration, comorbid conditions, and physical limitations.

Conclusions: Walking was associated with lower mortality across a diverse spectrum of adults with diabetes. One death per year may be preventable for every 61 people who could be persuaded to walk at least 2 h/wk.

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REGULAR PHYSICAL activity has been associated with reduced risk for cardiovascular disease (CVD), diabetes, and death in the general population.¹⁻⁶ Similarly, walking and other forms of exercise were key components of lifestyle changes shown to prevent progression to diabetes among people with impaired glucose tolerance.⁷⁻⁹ For people who already have diabetes, physical activity has been shown to improve insulin sensitivity, glycemic control, and CVD risk factors.¹⁰⁻¹²

Less clear, however, is the impact of physical activity, particularly simple activities such as walking, on the long-term outcomes of people with diabetes. Only 2 studies have examined the association of physical activity with the incidences of disease and death among persons with diabetes.^{13,14} Both studies associated physi-

cal activity with reduced CVD or all-cause mortality, but they were composed of participants who were younger and likely healthier than the general diabetic population.

*For editorial comment
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Diabetes leads to an array of disabling complications, including visual impairment, peripheral and autonomic neuropathy, silent ischemia, cardiac arrhythmias, and an increased risk for sudden death.¹⁵⁻¹⁷ These complications could make physical activity less feasible for people with diabetes and thereby limit its effects on the long-term health outcomes of the group as a whole. Physical activity also might not be as effective among people who have multiple comorbid conditions associated with diabetes.

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Because of these uncertainties about the effects of physical activity on people with diabetes, we attempted to determine how physical activity, particularly moderate-intensity activity, affects mortality risk across the full spectrum of adults with diabetes. In 1990 and 1991, special surveys examined physical activity as part of the National Health Interview Survey (NHIS), a representative sample of the US population.^{18,19} A follow-up of cause-specific mortality conducted in 1997²⁰ gave us a unique opportunity to examine the relationship of walking and other physical activities to mortality risk among US adults with diabetes.

METHODS

STUDY DESIGN AND POPULATION

The NHIS is an ongoing survey of the health status and behaviors of the US noninstitutionalized population.^{18,19} The NHIS uses multistage probability sampling to select approximately 45 000 households and 120 000 individuals each year. The overall response rate is approximately 95%. In this study, we used data on physical activity and health status collected from supplemental health promotion surveys conducted in 1990 and 1991 on a total of 84 836 randomly subsampled adult respondents (41 104 in a 1990 survey and 43 732 in a 1991 survey). The response rates for the supplements were 87% in 1990 and 92% in 1991.

Data from 82 985 (98%) of the respondents were linked to the National Death Index, a computer database of all deaths in the United States.²⁰ In the linked sample, 3506 individuals reported having diabetes. Of these, we excluded 78 persons who had missing data on physical activity, 123 who had missing data on covariates, and 409 who were disabled and thus not asked all the physical activity questions. This left 2896 persons for whom we examined the association between physical activity levels in 1990 through 1991 and mortality during the next 8 years.

DIABETES AND HEALTH STATUS MEASUREMENTS

In the 1990 and 1991 surveys, interviewers assessed diabetes status, age, race, sex, smoking, hypertension and use of antihypertensive medications, self-rated health (5-point scale ranging from excellent to poor), hospitalizations, and physician visits in the prior year. Participants also reported their height and weight, which were used to compute body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters) and were asked whether they were trying to lose weight and whether they were cutting calories, attending a special program, or using special products to lose weight. Participants were asked to describe activity limitations (ie, unable, limited, or not limited) and, if they had limitations, to identify the primary and secondary health conditions that led to the limitations. Using these responses, we categorized participants according to whether any CVD or cancer was a reported cause of their physical limitations. In the 1990 survey, participants were also asked whether they ever had a heart condition or stroke¹⁸ and in 1991, participants were asked their age at diabetes diagnosis and whether they take insulin.¹⁹

PHYSICAL ACTIVITY ASSESSMENT

In the 1990-1991 surveys, participants were asked how often they had walked for exercise during the previous 2 weeks, the average number of minutes they spent walking each time, and how much their heart and breathing rates increased (ie, no in-

crease, small, medium, or large) while walking.^{18,19,21} Participants were also asked whether they had participated in other sports or physical activities. Because the physical activities assessed in the 1990 and 1991 surveys varied slightly (eg, stretching was not assessed in 1990 and calisthenics were not assessed in 1991), we limited our assessment to the 10 most common physical activities that were assessed in both survey years. Aside from walking, these activities were gardening, jogging, aerobics, cycling, swimming, weight lifting, golf, basketball, and tennis. We then calculated the total number of hours per week that participants spent walking and the total hours per week they spent doing any leisure physical activity. Occupational physical activity was only assessed in the 1990 survey and was not included in these analyses.

MORTALITY ASSESSMENT

Mortality was determined by matching the respondent to the National Death Index using an algorithm provided by the National Center for Health Statistics to determine which matches should be classified as deaths.²⁰ The participants' vital status was available from the time of the survey (1990-1991) through December 31, 1997 (up to 8 years). Underlying causes of death were classified according to the codes of the *International Classification of Diseases, Ninth Revision*.²² Deaths coded 410 to 448 were classified as CVD deaths.

STATISTICAL ANALYSES

We used χ^2 tests and analysis of variance to compare study covariates according to walking level at baseline. Age-adjusted mortality rates were standardized to the age structure of the US population with diagnosed diabetes during the 1990-1991 survey period. We used Cox proportional hazards regression analyses to determine the mortality hazard rate ratio (HRR) associated with the numbers of hours per week they spent walking and performing any leisure activity and their self-perceived walking intensity, while adjusting for potentially confounding variables. Multivariate models controlled for age, race, sex, hypertension and the use of antihypertensive medications, weight loss approaches (as previously described), number of days hospitalized, smoking (former and current), CVD or cancer that could be attributed to impaired functioning, and the level of activity limitation in major daily activities. We also controlled for self-rated health because it is highly predictive of mortality,²³ and thus may account for additional variation in baseline health status among physical activity groups.

Because the duration of walking could vary with its intensity, we also examined the association between walking intensity and mortality, stratified by duration. Also, associations between walking and mortality could be explained by participation in other types of physical activity. Thus, we conducted additional analyses in which we controlled for total physical activity and excluded persons participating in moderate- or high-intensity activities (>5 metabolic equivalents), and reporting higher levels (>2 h/wk) of nonwalking physical activity.

We conducted additional analyses using the 1990 sample wherein we separately examined regression models to control for stroke and heart conditions. Similarly, we conducted analyses within the 1991 sample controlling for insulin use and time since diabetes diagnosis.

We examined several potential interactions, including whether the relationship between walking and mortality risk was modified by sex, race, age, BMI, or comorbid conditions (ie, functional limitations associated with CVD or cancer). We applied survey weights to make study estimates representative of the US noninstitutionalized adult population with diabetes. Analyses were conducted with SUDAAN version 7.5.4a software.²⁴

Table 1. Characteristics of the Study Population According to the Number of Hours Walked per Week*

Variable	Total	Walking Level, h/wk			P Value†
		0	>0-2	≥2	
No. of participants (weighted %)	2896 (100.0)	1551 (54.0)	726 (25.3)	619 (20.7)	
Women	52.5	54.1	53.6	47.1	.02
Age, y, mean	58.7	59.8	56.7	58.3	<.001
18-44	18.0	15.8	21.7	19.1	
45-64	43.2	42.6	45.2	42.1	
>65	38.8	41.6	33.1	38.8	
Race					
Non-Hispanic white‡	73.8	74.1	74.2	72.6	.85
Non-Hispanic black	16.6	16.0	14.6	16.1	
Hispanic	7.9	8.5	6.3	8.4	
Other	2.6	1.4	5.0	3.1	
BMI, mean	28.4	28.5	28.5	28.0	.38
<25	28.4	27.6	26.5	32.5	
25 to <30	39.2	39.0	41.3	37.5	
≥30	32.4	33.4	32.2	30.0	
Years since DM diagnosis, mean§	11.0	10.9	11.1	11.5	.72
Insulin use	35.9	34.8	37.3	36.9	.77
Smoking					
Current	20.1	22.8	14.9	19.6	<.001
Former	34.4	33.1	35.3	36.6	.40
Trying to lose weight	42.2	36.8	49.9	47.0	<.001
Self-rated health (fair or worse)	38.4	42.0	36.0	31.8	<.001
Physician visits past year, mean	8.6	8.8	7.5	8.6	.15
Any hospitalization in previous year	18.9	19.2	16.3	21.2	.11
Hypertension	56.0	55.5	56.5	56.7	.88
Heart disease¶	29.1	27.7	28.7	32.8	.32
Stroke¶	8.7	7.8	8.1	11.4	.31
Activity limitation	45.5	47.7	42.3	43.3	.04
Limitation caused by CVD	13.3	13.8	12.4	13.0	.73
Limitation caused by cancer	1.5	1.3	1.7	2.0	.55

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); CVD, cardiovascular disease; DM, diabetes mellitus.

*Unless otherwise indicated, data are expressed as percentages. Percentages have been rounded and may not sum to 100.

†Indicates test for heterogeneity across groups, unless otherwise indicated.

‡P values are based on comparison of non-Hispanic white subjects vs all other races.

§Denominator is reduced (n = 1466) because this was assessed only at 1 survey year.

||Denominator is reduced (n = 1490) because this was assessed only at 1 survey year.

¶Denominator is reduced (n = 1366) because this was assessed only at 1 survey year.

RESULTS

At baseline, the mean age of the population was 58.7 years (range, 18-95 years). Their mean BMI was 28.4, and their average time since diabetes diagnosis was 11.0 years (**Table 1**). Of the total population, 16.6% were non-Hispanic black, 7.9% were Hispanic, and 2.6% were of other nonwhite race/ethnicity. When characterized by BMI, 39.2% were overweight (BMI, 25-29) and 32.4% were obese (BMI, ≥30). In addition, 35.9% of the population reported using insulin, 29.1% reported heart disease, and 45.5% reported having a limitation in daily function.

In regard to walking, 46.0% of the population reported any walking for exercise and 20.7% reported walking for at least 2 h/wk. Aside from walking, the most commonly reported activities were gardening (25.1%), cycling (9.7%), weight lifting (4.0%), swimming (3.9%), aerobics (2.4%), jogging (2.4%), golf (2.1%), basketball (1.6%), and tennis (0.7%) (data not shown), and 61.8% reported performance of any leisure time physical activity.

Compared with less active persons, those reporting higher levels of walking were more likely to be men,

to report trying to lose weight, and to have better self-rated health ($P < .05$). Age, smoking prevalence, and activity limitations were lowest among those reporting some (>0 to 1.9 h/wk) walking ($P < .01$). Participants' race/ethnicity, BMI, time since diabetes diagnosis, insulin use, number of physician visits, hospitalizations, and history of hypertension, heart disease, and stroke, and activity limitations related to CVD and cancer were not significantly associated with their baseline walking level. During 8.0 years of follow-up, 671 study participants died (3.7/100 person-years), including 316 who died of CVD (1.7/100 person-years).

RELATIONSHIP BETWEEN PHYSICAL ACTIVITY AND MORTALITY

Higher levels of walking and total physical activity were each associated with a lower incidence of all-cause and CVD mortality (**Table 2**). Compared with participants who reported no walking, those who walked at least 2 h/wk had a 39% lower all-cause mortality rate (HRR, 0.61; 95% confidence interval [CI], 0.48-0.78) and a 34% re-

Table 2. Hazard Rate Ratios for All-Cause and CVD Mortality Associated With Walking and Total Physical Activity Among Persons With Diabetes

	Prevalence, %	All-Cause Mortality			CVD Mortality		
		Age-Adjusted Rate, % per Year	HRR (95% CI)* (n = 2896)	Excluding Disabled Persons (n = 2449)	Age-Adjusted Rate, % per Year	HRR (95% CI)* (n = 2896)	Excluding Disabled Persons (n = 2449)
Walking, h/wk							
0	54.0	4.44	1.00	1.00	2.05	1.00	1.00
>0-1.9	25.3	3.89	0.93 (0.74-1.16)	0.93 (0.72-1.20)	1.89	1.01 (0.76-1.34)	0.92 (0.67-1.25)
≥2	20.7	2.81	0.61 (0.48-0.78)	0.62 (0.48-0.80)	1.36	0.66 (0.45-0.96)	0.59 (0.40-0.87)
P value for trend	NA	NA	<.001	.002	NA	.08	.03
Total physical activity, h/wk							
0	38.2	4.45	1.00	1.00	2.05	1.00	1.00
0-1.9	25.5	4.20	0.95 (0.77-1.17)	0.89 (0.71-1.11)	1.96	0.96 (0.70-1.31)	0.81 (0.58-1.14)
≥2	36.3	3.05	0.71 (0.59-0.87)	0.66 (0.54-0.82)	1.49	0.76 (0.57-1.03)	0.70 (0.51-0.94)
P value for trend	NA	NA	.003	.001	NA	.19	.05

Abbreviations: CI, confidence interval; CVD, cardiovascular disease; HRR, hazard rate ratio; NA, not applicable.

*Controlled for age, sex, race, body mass index, self-rated health, smoking, weight loss approaches, hospitalizations, hypertension and use of antihypertensive medications, physician visits, limitations caused by CVD and cancer, and level functional limitation. All death rates are age adjusted to the US diabetic population.

duced CVD mortality risk (HRR, 0.66; 95% CI, 0.45-0.96), controlled for age, sex, race, BMI, smoking, utilization of health care services, attempts to lose weight, and comorbid conditions. Participants who reported at least 2 h/wk of total leisure-time physical activity had a 29% lower all-cause mortality risk (HRR, 0.71; 95% CI, 0.59-0.87) and a 24% (nonsignificantly) lower CVD mortality risk (HRR, 0.76; 95% CI, 0.57-1.03) than inactive participants. The associations among walking, physical activity, and lowered mortality were similar or slightly stronger when we excluded persons with disability. We also found similar walking-related mortality rate reductions after we excluded deaths that occurred in the 2 years of follow-up (data not shown).

The reduction in mortality corresponded to a 1.6% absolute difference in age-adjusted, all-cause annual mortality between those who walked at least 2 hours (2.8%) and those who did not walk (4.4%) and a 0.7% difference in annual CVD mortality rates between those who walked at least 2 hours (1.4%) and those who did not walk (2.1%). Thus, among diabetic adults, one death per year may be preventable for every 61 people who could be persuaded to walk at least 2 h/wk. One CVD death per year may be preventable for every 145 persuaded to walk at least 2 h/wk.

We found that controlling for participants' insulin status and disease duration using data from the 1991 survey had little effect on the association between walking and mortality (data not shown). Similarly, controlling for heart trouble and history of stroke using the 1990 survey sample did not alter the association between walking and mortality. However, the CIs for these associations were broader because these analyses relied on only half of the overall sample.

WALKING DURATION AND INTENSITY AND MORTALITY

We found that a greater duration of walking was associated with a lower all-cause mortality rate (for trend, $P=.004$) (**Table 3**). The greatest risk reduction was

among those walking 3 to 3.9 h/wk (HRR, 0.46; 95% CI, 0.29-0.71). This group had a similar reduction in CVD mortality risk (HRR, 0.47; 95% CI, 0.24-0.91), but we found no significant linear trend, and the surrounding point estimates were broader because of the smaller number of CVD deaths. The association between time spent walking and mortality rates was similar after we excluded deaths that occurred during the first 2 years of follow-up (data not shown). We also found that controlling for physical activity other than walking and excluding persons who participated in moderate or vigorous activities or performed greater than 2 h/wk of nonwalking physical activity had no appreciable effect on the association between walking and mortality.

Higher levels of perceived walking intensity were associated with a reduced all-cause mortality rate (for trend, $P=.006$). Compared with participants who reported no walking, those who reported no, some, and moderate increases in heart rate or breathing rate had reductions in mortality rates of 5% (HRR, 0.95; 95% CI, 0.76-1.17), 31% (HRR, 0.69; 95% CI, 0.51-0.95), and 43% (HRR, 0.57; 95% CI, 0.41-0.80), respectively. Those who reported large increases in heart rate or breathing rate did not have significantly reduced all-cause mortality (HRR, 0.93; 95% CI, 0.50-1.71), but the risk reduction was greater after we excluded deaths that occurred in the first 2 years of follow-up (HRR, 0.66; 95% CI, 0.34-1.29) (data not shown). Only 3% of the population reported large increases in heart rate or breathing rate with walking, and limited statistical power (22 deaths) was available to examine mortality in this group.

Associations between perceived walking intensity and CVD mortality were weaker than for all-cause mortality. Again, we found the greatest reductions in CVD mortality risk were among those who reported moderate increases in heart rate or breathing rate while walking, although the association was not statistically significant (HRR, 0.69; 95% CI, 0.43-1.09). Participants who reported large increases in heart rate or breathing rate had a nonsignificant 12% increased mortality risk (HRR, 1.12; 95% CI, 0.45-2.78), but after excluding the first 2 years

Table 3. Hazard Rate Ratios for All-Cause and CVD Mortality Associated With Walking Duration and Perceived Intensity Among Persons With Diabetes

	Prevalence, %	All-Cause Mortality		CVD Mortality	
		Age-Adjusted Rate, % per Year	HRR (95% CI)*	Age-Adjusted Rate, % per Year	HRR (95% CI)*
Walking duration, h/wk					
0	54.0	4.44	1.00	2.05	1.00
>0-0.9	12.9	4.42	1.00 (0.76-1.30)	2.26	1.16 (0.81-1.66)
1-1.9	12.4	3.36	0.86 (0.62-1.18)	1.52	0.84 (0.53-1.31)
2-2.9	5.7	2.70	0.61 (0.41-0.91)	1.40	0.81 (0.50-1.31)
3-3.9	5.8	2.11	0.46 (0.29-0.71)	0.94	0.47 (0.24-0.91)
≥4	9.2	3.17	0.72 (0.51-1.03)	1.30	0.67 (0.39-1.17)
P value for trend	NA	NA	.004	NA	.20
Perceived walking intensity					
No walking	54.5	4.44	1.00	2.05	1.00
Increase in heart rate/breathing rate					
None	16.2	3.82	0.95 (0.76-1.17)	1.62	0.91 (0.66-1.25)
Some	13.4	3.14	0.69 (0.51-0.95)	1.63	0.77 (0.49-1.20)
Moderate	12.6	2.73	0.57 (0.41-0.80)	1.57	0.69 (0.43-1.09)
Large	3.4	3.84	0.93 (0.50-1.71)	1.59	1.12 (0.45-2.78)
P value for trend	NA	NA	.006	NA	.38

Abbreviations: CI, confidence interval; CVD, cardiovascular disease; HRR, hazard rate ratio; NA, not applicable.

*Controlled for age, sex, race, body mass index, self-rated health, smoking, weight loss approaches, hospitalizations, hypertension and use of antihypertensive medications, physician visits, limitations caused by CVD and cancer, and level of functional limitation. All death rates are age adjusted to the US diabetic population.

Table 4. Hazard Rate Ratio for All-Cause and CVD Mortality Associated With Walking Duration and Perceived Intensity Among Persons With Diabetes

Walking Duration,* Perceived Walking Intensity†	% of Population	Age-Adjusted Rate, % per Year	All-Cause Mortality, HRR (95% CI)‡
0			
NA	54.5	4.44	1.00
>0-1.9			
None	8.0	4.39	1.23 (0.89-1.72)
Some	7.7	4.35	0.83 (0.56-1.22)
Moderate	7.5	2.91	0.70 (0.45-1.08)
Large	2.0	4.19	0.89 (0.44-1.81)
≥2			
None	8.2	3.40	0.74 (0.54-1.01)
Some	5.7	2.37	0.55 (0.35-0.86)
Moderate	5.1	2.52	0.44 (0.28-0.68)
Large	1.4	3.10	0.99 (0.32-3.04)

Abbreviations: CI, confidence interval; CVD, cardiovascular disease; HRR, hazard rate ratio; NA, not applicable.

*Measured as hours per week.

†Measured as an increase in heart rate or breathing rate.

‡Controlled for age, sex, race, body mass index, self-rated health, smoking, weight loss approaches, hospitalizations, hypertension and use of antihypertensive medications, physician visits, limitations caused by CVD and cancer, and level of functional limitation.

of follow-up, we found this group to have a nonsignificant, 24% reduced mortality risk (HRR, 0.76; 95% CI, 0.24-2.44) (data not shown).

When we categorized individuals by combining time spent walking and perceived walking intensity (**Table 4**), the lowest mortality rates were for those who reported walking at least 2 h/wk with some increases in heart rate or breathing rate (HRR, 0.55;

95% CI, 0.35-0.86) or moderate increases in heart rate or breathing rate (HRR, 0.44; 95% CI, 0.28-0.68). Large increases in heart rate or breathing rate were not significantly associated with mortality risk, regardless of the time spent walking, but again the statistical power was limited by the small sample size and number of deaths (n=9).

SUBGROUP ANALYSES

When we stratified our analyses, the magnitude of the all-cause mortality risk reduction associated with walking at least 2 h/wk did not vary appreciably according to participants' sex, age, race, obesity, time since diabetes diagnosis, functional limitations, or presence of comorbid conditions. The greatest difference in HRRs was for the comparison between those with (HRR, 0.72; 95% CI, 0.52-0.99) and without comorbid conditions (HRR, 0.52; 95% CI, 0.36-0.75) (**Figure**). However, we found no statistically significant interactions between physical activity level and any of these stratifications. Confidence intervals were broader and overlapped 1 in some cases, because there were fewer individuals in several of these strata. Also, we had inadequate power to assess associations with mortality among persons who were more likely to have type 1 diabetes (132 persons, or 7.4% of the 1991 sample), but we found no difference in results when we excluded these persons from our analyses.

COMMENT

In this nationally representative sample of Americans with diabetes, higher levels of walking and total lei-

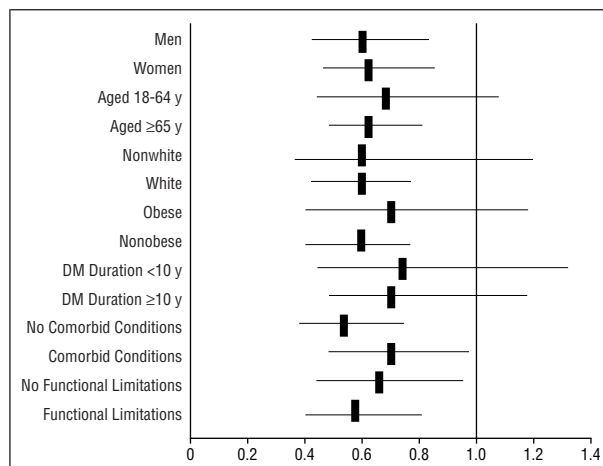
sure time physical activity were associated with significant reductions in all-cause and CVD mortality. Specifically, walking at least 2 h/wk was associated with a 34% to 39% reduction in all-cause and CVD mortality rate, and even greater amounts of walking (ie, about 3-4 h/wk) were associated with up to a 54% reduction in mortality. We also found that walking at moderate intensity levels was associated with the greatest reduction in mortality rates. Overall, these findings support current recommendations that brisk walking on a regular basis is a key health behavior for persons with type 2 diabetes.^{11,12}

Our findings are also consistent with those of 2 previous studies conducted among younger and healthier populations with diabetes.^{13,14} Among middle-aged (mean age, 50 years) men with type 2 diabetes in the Aerobics Center Longitudinal Study, physical activity was associated with reduced all-cause mortality.¹³ In the Nurses' Health Study, moderate and vigorous physical activity were associated with reduced rates of overall cardiovascular events, coronary heart disease events, and ischemic strokes among diabetic women aged 30 to 55 years who were free of CVD at baseline.¹⁴ Our study complements these earlier studies by examining a nationally representative sample that was probably more diverse and had more comorbid conditions typical of diabetic persons. This diversity enhances the validity when making inferences to the overall diabetic population.

Persons with diabetes have a high prevalence of microvascular and macrovascular diseases²⁵ and functional limitations²⁶ that could make exercise more difficult. The complications of diabetes could also conceivably increase their risk for CVD events, falls, injuries, or foot ulcers.²⁷⁻²⁹ Thus, health care providers may be reluctant to encourage physical activity. However, our results suggest that the effects of walking on longevity extend across these diverse characteristics, with roughly equal benefit regardless of age, sex, race, BMI, time since diabetes diagnosis, or presence of comorbid conditions and functional limitations.

Walking could lengthen the life of people with diabetes in several ways. Among people without diabetes, physical activity has been related to increased high-density lipoprotein cholesterol levels,^{30,31} decreased blood pressure,³² decreased insulin levels,³³ increased cardiorespiratory fitness,³⁴ and if accompanied by weight loss, decreased low-density lipoprotein cholesterol levels.^{30,31} Among diabetic persons, regular exercise is also associated with improved insulin sensitivity and glycemic control.¹⁰ These effects could help reduce the incidence of cardiovascular events and/or reduce mortality among those who already have cardiovascular disease.³⁵ Finally, in the presence of multiple chronic diseases, exercise may forestall functional decline^{36,37} and may delay death through other unexplained mechanisms.

We found the lowest mortality rates among persons reporting moderate increases in perceived heart and breathing rates, but we found no mortality reduction associated with large perceived increases in heart and breathing rates. One might conclude from this latter observation that more intense levels of walking are



Hazard rate ratios and 95% confidence intervals for all-cause mortality associated with walking for greater than 2 h/wk (vs no walking) according to participant characteristics. The analyses were controlled for age, sex, race, body mass index, self-rated health, smoking, weight loss approaches, hospitalizations, hypertension and the use of antihypertensive medications, physician visits, limitations caused by cardiovascular disease (CVD) and cancer, and level of functional limitation. Examination within duration of disease strata additionally controlled for insulin use. Comorbid conditions are defined as any functional limitations associated with CVD or cancer or a history of hospitalization during past year; limitation, as any self-reported limitation in major activity. DM indicates diabetes mellitus.

not as beneficial for people with type 2 diabetes. However, a large perceived increase in heart rate or breathing rate during walking might be a marker of exertional coronary ischemia or other undetected cardiovascular or pulmonary disease.² If true, higher mortality rates among people with large perceived increases in heart rate/breathing rate could have been due to underlying disease rather than the intensity of exercise performed. This explanation is consistent with our finding that the amount of risk reduction associated with large perceived increases in heart rate or breathing rate was similar to those with small or moderate increases when we excluded deaths that occurred during the first 2 years of follow-up.

Our study has several limitations. Participants' diabetes status was based on self-reports, which are highly sensitive and specific for previously diagnosed diabetes, but clearly miss individuals with undiagnosed diabetes.³⁸ Thus, we may not be able to generalize our findings to those with undiagnosed diabetes. In addition, we had inadequate power to examine associations among persons who were more likely to have type 1 diabetes, and the long-term effects of physical activity among that subgroup remains unclear.

Our analyses focused on walking because it is the most commonly performed and one of the safest forms of physical activity. However, we cannot generalize our findings to other specific activities or to physical activities not included in the NHIS surveys (eg, household, transportation, and work-related physical activities). Also, because physical activity was measured by means of self-report during a 2-week time frame, it may not be representative of usual activity for all persons. However, physical activity surveys with a similar format and time frame have been shown to have high test-retest reliability and moderate correlations with energy expenditure

using the doubly labeled water technique and to be predictive of CVD and mortality in the general population.²¹ The reliability and validity of self-reported exercise intensity assessed in epidemiological studies is less clear. However, breathing and heart rate responses have been shown to be central cues to perceived exertion, which are highly correlated with actual workload in experimental settings.³⁹ We also lacked detailed information on dietary composition, which may be associated with physical activity and could similarly reduce mortality. However, our findings were not changed when we controlled for whether persons were trying to reduce calories or were enrolled in special programs to lose weight.

Finally, we cannot rule out underlying health status as one of the factors explaining why physical activity was associated with decreased mortality risk. Sicker persons may have chosen not to be physically active because of chronic conditions or subclinical disease not measured by this study. However, we found that people reporting higher levels of walking at baseline actually had nonsignificantly higher levels of stroke, heart disease, and hospitalization at baseline than those reporting no walking. In addition, our analyses controlled for variation in utilization of health care services, self-rated health, and functional limitations associated with chronic conditions, and our findings were essentially unchanged when we conducted analyses among a subsample who had been asked specifically about heart disease and stroke.

Many important questions remain about the effects of physical activity on the long-term disease outcomes of people with diabetes. Although physical activity leads to numerous physiological benefits, and although our findings suggest that walking increases longevity among patients with diabetes, the direct relationships between physical activity and the incidence of microvascular and macrovascular complications, disability incidence, or quality of life among persons with diabetes have not been established. We lack data on adverse events that could conceivably result from physical activity, including hypoglycemia, foot ulcers, falls, and sudden cardiac death. We also lack the data needed to assess the intervening roles of factors such as glycemic control, weight loss, control of CVD risk factors, and specific incident events such as heart attack and stroke. Thus, it is important for future studies to clearly determine the mechanisms whereby walking and physical activity reduce mortality risk, and conduct randomized controlled trials to test the effects of specific types and amounts of physical activity on long-term health outcomes.

The prevalence of diabetes and physical inactivity are both high in the United States.^{40,41} Our findings that regular walking is likely to increase longevity across a diverse spectrum of adults with diabetes means that successful efforts to increase physical activity levels of the US diabetic population could have broad public health benefits. To be successful, however, such efforts may depend on a combination of approaches, including community-based programs, effective health promotion through the health care system, and environmental and cultural changes.

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