Standing and Mortality in a Prospective Cohort of Canadian Adults

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ABSTRACT

KATZMARZYK, P. T. Standing and Mortality in a Prospective Cohort of Canadian Adults. *Med. Sci. Sports Exerc.*, Vol. 46, No. 5, pp. 940–946, 2014. **Purpose**: Several studies have documented significant associations between sedentary behaviors such as sitting or television viewing and premature mortality. However, the associations between mortality and other low-energy-expenditure activities such as standing have not been explored. The purpose of this study was to examine the association between daily standing time and mortality among 16,586 Canadian adults 18–90 yr of age. **Methods**: Information on self-reported time spent standing as well as several covariates including smoking, alcohol consumption, physical activity readiness, and moderate-to-vigorous physical activity was collected at baseline in the 1981 Canada Fitness Survey. Participants were followed for an average of 12.0 yr for the ascertainment of mortality status. **Results**: There were 1785 deaths (743 from cardiovascular disease [CVD], 530 from cancer, and 512 from other causes) in the cohort. After adjusting for age, sex, and additional covariates, time spent standing was negatively related to mortality rates from all causes, CVD, and other causes. Across successively higher categories of daily standing, the multivariable-adjusted hazard ratios were 1.00, 0.79, 0.79, 0.73, and 0.67 for all-cause mortality (*P* for trend <0.0001); 1.00, 0.82, 0.84, 0.68, and 0.75 for CVD mortality (*P* for trend 0.02); and 1.00, 0.76, 0.63, 0.67, and 0.65 for other mortality (*P* for trend <0.001). There was no association between standing and cancer mortality. There was a significant interaction between physical activity and standing ($P < 0.05$), and the association between standing and mortality was significant only among the physically inactive (<7.5 MET·h·wk^{-1}). **Conclusions**: The results suggest that standing may not be a hazardous form of behavior. Given that mortality rates declined at higher levels of standing, standing may be a healthier alternative to excessive periods of sitting. **Key Words:** POSTURE, STANDING, PHYSICAL ACTIVITY, CANADA FITNESS SURVEY, DEATH, COHORT

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There is considerable interest in understanding the association between sedentary behavior and health (14,19,37). Several recent longitudinal studies have documented relationships between sedentary behaviors including television viewing or total sitting time and health outcomes such as type 2 diabetes and mortality from all-causes and from cardiovascular disease (10,35,43). Many of these studies used multivariable modeling or stratification strategies that suggest that the effects of sedentary behavior may be independent of leisure-time moderate-to-vigorous physical activity (MVPA) (7,20,25,28,32,40,41).

The definition of sedentary behavior has evolved over the last several years (26,27,37). One recent definition proposes that sedentary behavior should be defined as "any waking behavior characterized by an energy expenditure ≤1.5 METs while in a sitting or reclining posture" (30). A key component of this definition is the focus on sitting or reclining, indicating that standing is not included in the definition, although the energy expenditure associated with standing quietly is approximately 1.2 METs (1). Indeed, the word sedentary comes from the Latin word "*sedēre*," which literally means to "sit" (34). There is some evidence that sitting and standing, although both evoking low levels of energy expenditure, may represent different physiological states (12,13). Standing engages a large muscle mass in the lower extremities, which becomes inactive when in the seated posture (13).

Given that sitting and standing are both low-energy behaviors and that recommendations to reduce sitting time may be offset by extended periods of standing, it is of interest to understand the association between standing and mortality. If greater time spent standing is associated with an increased risk of mortality, it may be prudent to consider standing a "hazardous" behavior, similar to seated activities. On the other hand, if greater time spent standing is associated with a lower risk of mortality then standing may be considered a healthier alternative to sitting. A significant positive association between daily sitting time and mortality has been reported among adults from the Canada Fitness Survey (20). The purpose of the present study was to examine the association between daily standing time and mortality among 16,586 Canadian adults 18–90 yr of age.

METHODS

Sample. The sample included men and women from urban and rural areas of every Canadian province who participated

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in the 1981 Canada Fitness Survey (CFS), which was a nationally representative sample of the Canadian population (6). Approximately 3% of the total population was excluded from the sampling frame, including aboriginal people living on reserves, institutionalized persons, armed forces personnel living on bases, and residents of the Territories and remote areas. A total of 23,400 people participated in some element of the CFS; however, the sample used in this study included 16,586 men and women between the ages of 18 and 90 yr for whom the required baseline measurements were available. All protocols were reviewed, and approval was obtained from a panel of experts working in the field of exercise science at the time of the baseline Canada Fitness Survey. Data analysis was approved by the Pennington Biomedical Center Institutional Review Board.

Baseline assessment. To assess the primary exposure variable, respondents completed a questionnaire and answered the following question: "For those activities which you do most days of the week (such as work, school and housework), how much time do you spend standing?" Responses included 1) almost all of the time, 2) about three fourths of the time, 3) about one half of the time, 4) about one fourth of the time, and 5) almost none of the time (6).

Information on several covariates was collected for inclusion in the statistical models. Age was determined from birth and observation dates and was coded as a continuous variable (*y*). A lifestyle questionnaire was administered, and the smoking status of participants was coded as nonsmokers, former smokers, or current smokers. Alcohol consumption was categorized as abstainer, <10 drinks per month, 10–50 drinks per month, and >50 drinks per month. Leisure-time MVPA levels were calculated in MET-hours per week by summing the products of the metabolic costs of each activity, its duration, and the average occasions per week across a 12-month recall period, using a questionnaire modeled on the Minnesota Leisure Time Physical Activity Questionnaire (33).

Information on conditions such as cardiovascular disease, cancer, and diabetes was not available at baseline. However, to account for possible confounding, data from the Physical Activity Readiness Questionnaire (PAR-Q) were included as a covariate (pass/fail/missing). The PAR-Q asks several questions regarding heart trouble, chest pain, high blood pressure, dizzy spells, joint problems, and other problems that may prevent participants from participating in physical activities (3). A positive response to any question results in a failure of the PAR-Q.

Ascertainment of mortality. The CFS database was linked to the Canadian Mortality Database by Statistics Canada, which contains all recorded deaths in Canada since 1950 and is regularly updated using death registrations supplied by every province and territory. Record linkage was performed using computerized probabilistic techniques, and the potential for death linkages to be missed using the method used by Statistics Canada is quite small (29,31). All deaths occurring between the end of CFS data collection (1981) through December 31, 1993, were included in the analysis. A total of 1785 deaths occurred during a mean ± SD of 12.0 ± 2.1 yr of follow-up, yielding 199,584 person-years of follow-up.

Statistical analyses. Kaplan–Meier survival curves were plotted to examine differences in cumulative survival across categories of daily standing time, and differences were compared with log-rank statistics. Age-adjusted all-cause mortality rates per 10,000 person-years of follow-up were computed across categories of daily standing time, separately in men and women. Cox proportional hazards regression was used to estimate hazard ratios (HRs) and 95% confidence intervals (CI) for the association between standing and mortality. The results from two models are presented: 1) adjusted for age and sex and 2) additionally adjusted for smoking status (former, current, nonsmoker), alcohol consumption (abstainer, <10 drinks per month, 10–50 drinks per month, >50 drinks per month), leisure-time physical activity ($MET \cdot h \cdot wk^{-1}$), and the PAR-Q (pass/fail/missing). Tests of linear trends in mortality rates were conducted using ordinal scaling across categories of daily standing time. The primary endpoints were mortality from all-causes, cardiovascular disease (*ICD-9* codes 390–449), cancer (*ICD-9* codes 140–239), and other causes (all other *ICD-9* codes).

To examine the independent effects of standing and MVPA, HRs were computed across combined categories of standing (five categories) and MVPA (active ≥7.5 $MET \cdot h \cdot wk^{-1}$, inactive <7.5 $MET \cdot h \cdot wk^{-1}$), with the physically inactive/standing "almost none of the time" group as the reference category. Sex-by-standing and physical activity-by-standing interaction terms were used to examine interaction effects in the models. To minimize the potential confounding effects of occult disease at baseline, the primary analyses were repeated after eliminating all deaths that occurred during the first year of follow-up. All analyses were conducted using SAS 9.3 (SAS Institute, Inc., Cary, NC).

RESULTS

The descriptive characteristics of the sample are presented in Table 1. In the overall sample, 15.3% reported standing almost none of the time, 37.5% one fourth of the time, 23.8% one half of the time, 13.6% three quarters of the time, and 9.7% almost all of the time. Mean ± SD age and body mass index of the sample at baseline was 42.0 ± 17.5 yr and 24.3 ± 4.0 $kg \cdot m^{-2}$, respectively.

There were 1785 deaths (743 from cardiovascular disease [CVD], 530 from cancer, and 512 from other causes) in the cohort during a mean of 12.0 yr of follow-up. Figure 1 shows the Kaplan–Meier survival curves for all-cause mortality across categories of daily standing. There is a strong relationship between standing time and cumulative survival (log-rank χ^2 = 175.9, df = 4, P < 0.0001), with crude death rates of 144, 94, 85, 58, and 45 per 10,000 person-years across decreasing levels of daily standing.

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TABLE 1. Baseline descriptive characteristics[a] of 16,586 men and women from the Canada Fitness Survey across levels of daily standing time.

	Almost None of the Time	One Fourth of the Time	Half of the Time	Three Fourths of the Time	Almost All of the Time
Men					
n	1293	2698	1471	856	745
Age (yr)	44.5 ± 18.6	43.1 ± 17.7	42.2 ± 17.7	38.3 ± 15.6	37.3 ± 14.4
Physical activity (MET·h·wk^{-1})	11.7 ± 14.5	13.4 ± 15.9	13.2 ± 15.2	13.2 ± 16.1	11.8 ± 15.3
Physical activity level (≥7.5 MET·h·wk^{-1} (%))	45.0	50.7	51.1	50.5	43.8
Body mass index (kg·m^{-2})	25.0 ± 3.6	25.2 ± 3.6	25.2 ± 3.7	24.6 ± 3.5	25.0 ± 3.6
Smoking status (%)					
Nonsmoker	30.4	30.2	29.7	27.2	24.2
Former smoker	27.6	25.5	25.8	24.1	24.7
Current smoker	41.9	44.3	44.6	48.8	51.2
Alcohol consumption (%)					
Abstainer	18.5	15.5	16.8	14.3	15.4
<10 drinks per month	29.8	29.6	29.5	30.4	29.6
10–50 drinks per month	40.6	43.5	40.7	40.3	40.7
>50 drinks per month	11.1	11.4	12.9	15.0	14.3
Physical Activity Readiness (PAR-Q %)					
Pass	54.9	57.5	53.8	59.8	61.2
Fail	10.4	9.7	9.9	8.9	9.0
Missing	34.7	32.8	36.2	31.3	29.8
Women					
n	1255	3529	2472	1403	864
Age (yr)	43.9 ± 19.7	42.4 ± 18.0	42.5 ± 17.3	40.6 ± 15.5	38.8 ± 14.6
Physical activity (MET·h·wk^{-1})	9.7 ± 12.7	10.4 ± 13.4	10.5 ± 13.2	10.4 ± 13.8	9.6 ± 12.0
Physical activity level (≥7.5 MET·h·wk^{-1} (%))	41.4	42.7	45.2	41.6	41.4
Body mass index (kg·m^{-2})	23.3 ± 4.1	23.7 ± 4.3	23.8 ± 4.2	23.7 ± 4.3	23.8 ± 4.4
Smoking status (%)					
Nonsmoker	45.5	48.2	51.4	48.6	46.1
Former smoker	16.2	16.0	14.9	14.8	14.1
Current smoker	38.3	35.8	33.7	36.6	39.8
Alcohol consumption (%)					
Abstainer	31.0	28.9	31.4	33.3	34.8
<10 drinks per month	41.8	43.2	44.5	44.5	46.8
10–50 drinks per month	25.2	25.6	22.5	19.9	16.1
>50 drinks per month	2.0	2.3	1.6	2.3	2.4
Physical Activity Readiness (PAR-Q %)					
Pass	44.6	47.3	48.3	50.1	49.1
Fail	12.8	11.6	11.3	12.8	12.7
Missing	42.6	41.1	40.4	37.1	38.2

[a]Results are presented as mean ± SD for continuous variables and percentage (%) for categorical variables.

The results of the proportional hazards regression analyses are presented in Table 2. In both the age-adjusted and multivariable-adjusted analyses, there were significant negative linear trends across successive levels of daily standing for all-cause mortality, CVD mortality, and mortality from other causes. The multivariable-adjusted HR across successive standing groups were 1.00, 0.79, 0.79, 0.73, and 0.67 (*P* for trend <0.0001) for all-cause mortality; 1.00, 0.82, 0.84, 0.68, and 0.75 (*P* for trend 0.02) for CVD mortality; and 1.00, 0.76, 0.63, 0.67, and 0.65 (*P* for trend <0.001) for other mortality. There were no significant linear trends for cancer mortality; however, the HR for the highest standing group was significantly lower than the lowest standing group (HR = 0.63; 95% CI = 0.41–0.97).

A sex-by-standing group interaction term was entered into the proportional hazards regression model and was not significant ($P = 0.08$). There were significant negative linear trends in age-adjusted all-cause mortality rates across successive levels of daily standing (Fig. 2) in both men ($P < 0.04$) and women ($P < 0.0001$). Figure 3 presents the results of the analysis of the combined influence of leisure-time physical activity and daily standing time. The physically inactive group that reported standing almost none of the time served as the reference group with which all other groups were compared. A physical activity-by-standing group interaction term was entered into the proportional hazards multivariable regression model and was found to be significant ($P < 0.05$). Thus, analyses were stratified by physical activity level, and the results indicated a significant linear trend in those who were physically inactive ($n = 9041$) ($P < 0.0001$) but not in those who were active ($n = 7545$) ($P = 0.2$).

Sensitivity analyses that excluded deaths that occurred during the first year of follow-up ($n = 95$) were conducted, and the results were similar. For example, there were significant linear trends for all-cause, CVD, and other mortality, but not for cancer mortality, in both the age- and multivariable-adjusted models.

DISCUSSION

The results indicate that greater time spent standing is associated with a lower risk of mortality. The observed association is consistent in men and women; however, it seems to be limited to those who are physically inactive. Several

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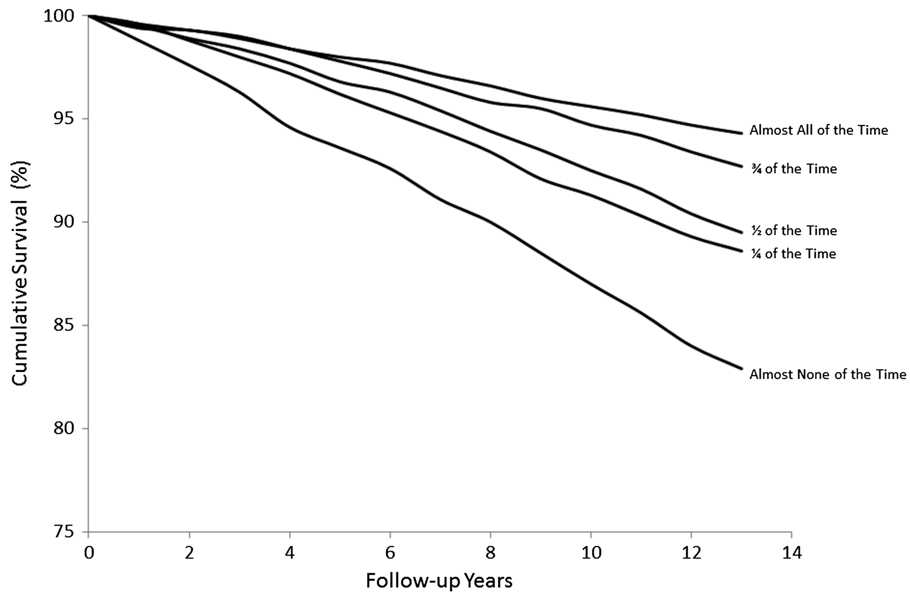

FIGURE 1—Kaplan–Meier survival curve for all-cause mortality across categories of daily standing time in 16,586 men and women 18–90 yr of age, in the Canada Fitness Survey, 1981–1993. Log-rank χ^2 = 175.9, *df* = 4, *P* < 0.0001. The sample sizes across the categories were 2543 (15.3%), 6227 (37.5%), 3943 (23.8%), 2259 (13.6%), and 1609 (9.7%), for the categories of standing almost none of the time, one fourth of the time, half of the time, three fourths of the time, and almost all of the time, respectively.

epidemiological studies have documented high levels of sitting and sedentary behavior internationally (2,15,24). Given preliminary evidence that breaks in sedentary behavior are associated with a more favorable cardiometabolic risk profile (8,17,18), and the emerging evidence of associations between excessive sitting and the development of several chronic diseases and premature mortality (35,43), standing may represent a healthier alternative to sedentary behaviors. There is a clear dose–response relationship between standing and mortality; however, the greatest reduction in risk occurs between those who reported standing "almost none of the time" and those who reported standing "one quarter of the time." This parallels the results from previous studies that have demonstrated that the greatest reduction in mortality and heart disease risk associated with aerobic fitness and MVPA levels occurs when moving out of the least fit or least active categories (4,42).

Sitting and standing are behaviors at the low end of the energy expenditure continuum, and neither would be considered "physical activities." The recent definition of sedentary behavior by the Sedentary Behavior Research Network is focused solely on behaviors conducted in a sitting or reclining posture (30). If associations with health outcomes are considered important in establishing the definition of sedentary behavior then the results of this study would lend support to the idea of excluding standing from the definition and focusing specifically on sitting and reclining.

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TABLE 2. Risk of all-cause, cardiovascular disease, cancer, and other mortality associated with daily standing time in 16,586 men and women from the Canada Fitness Survey, 1981–1993.

	Almost None of the Time	One Fourth of the Time	Half of the Time	Three Fourths of the Time	Almost All of the Time	*P* for Trend
n	2548	6227	3943	2259	1609	
Person-years of follow-up	29,634	74,746	47,683	27,694	19,827	
All-cause mortality						
Deaths	426	702	406	161	90	
Age- and sex-adjusted hazard ratio (95% CI)	1.00	0.77 (0.68–0.87)	0.76 (0.66–0.87)	0.71 (0.59–0.85)	0.68 (0.54–0.85)	*P* < 0.0001
Multivariable-adjusted hazard ratio[a] (95% CI)	1.00	0.79 (0.70–0.90)	0.79 (0.69–0.91)	0.73 (0.61–0.88)	0.67 (0.54–0.85)	*P* < 0.0001
Cardiovascular disease mortality						
Deaths	185	300	170	54	34	
Age- and sex-adjusted hazard ratio (95% CI)	1.00	0.80 (0.67–0.96)	0.81 (0.65–0.99)	0.65 (0.48–0.88)	0.75 (0.52–1.09)	*P* = 0.01
Multivariable-adjusted hazard ratio[a] (95% CI)	1.00	0.82 (0.68–0.99)	0.84 (0.68–1.03)	0.68 (0.50–0.92)	0.75 (0.52–1.09)	*P* = 0.02
Cancer mortality						
Deaths	113	197	135	59	26	
Age- and sex-adjusted hazard ratio (95% CI)	1.00	0.79 (0.62–0.99)	0.90 (0.70–1.15)	0.88 (0.64–1.20)	0.63 (0.41–0.98)	NS
Multivariable-adjusted hazard ratio[a] (95% CI)	1.00	0.81 (0.64–1.02)	0.94 (0.73–1.21)	0.89 (0.65–1.23)	0.63 (0.41–0.97)	NS
Other mortality[b]						
Deaths	128	205	101	48	30	
Age- and sex-adjusted hazard ratio (95% CI)	1.00	0.73 (0.59–0.91)	0.60 (0.46–0.78)	0.64 (0.45–0.89)	0.65 (0.44–0.97)	*P* = 0.001
Multivariable-adjusted hazard ratio[a] (95% CI)	1.00	0.76 (0.61–0.95)	0.63 (0.49–0.82)	0.67 (0.48–0.93)	0.65 (0.43–0.97)	*P* = 0.002

[a]Adjusted for age (as a continuous variable), sex, smoking (former, current, nonsmoker), alcohol consumption (abstainer, <10 drinks per month, 10–50 drinks per month, >50 drinks per month), leisure time physical activity (as a continuous variable, MET·h·wk^{-1}), and the Physical Activity Readiness Questionnaire (pass/fail/missing).
[b]Other mortality includes all deaths that were not coded as cardiovascular disease or cancer.

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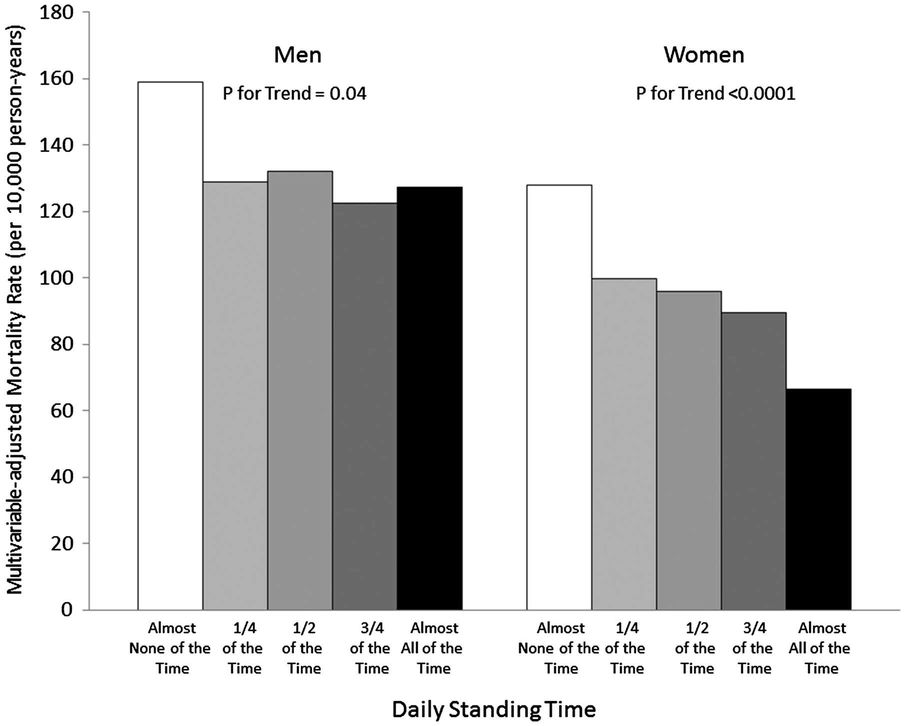

FIGURE 2—Multivariable-adjusted all-cause mortality rates across daily categories of standing in 16,586 men and women 18–90 yr of age, in the Canada Fitness Survey, 1981–1993. Mortality rates are adjusted for age (as a continuous variable), smoking (former, current, nonsmoker), alcohol consumption (abstainer, <10 drinks per month, 10–50 drinks per month, >50 drinks per month), leisure-time physical activity (as a continuous variable, MET·h·wk^{-1}), and the Physical Activity Readiness Questionnaire (pass/fail/missing).

The association between standing and mortality in this study was observed only among individuals who were not meeting physical activity recommendations. It is widely acknowledged that engagement in daily MVPA has many health benefits and should be universally promoted (39). There is a clear dose–response relationship between levels of MVPA and a variety of health outcomes (22). There is also evidence that levels of "light" or "lifestyle" activities are positively associated with health benefits (5,23), which provides further evidence for a dose–response relationship between human movement and health. The results of this study add to this evidence by showing that individuals who are not gaining the benefits of a physically active lifestyle can at least mitigate some of the health hazards associated with physical inactivity by

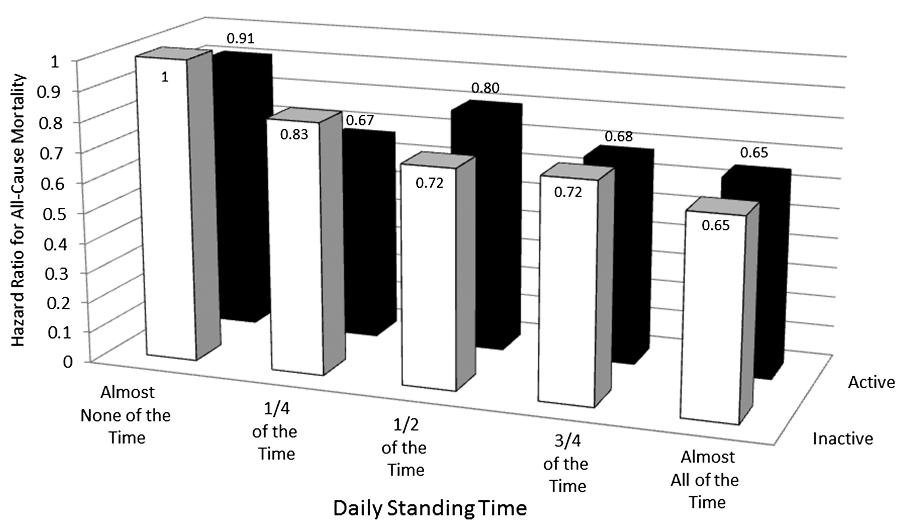

FIGURE 3—Multivariable-adjusted hazard ratios for all-cause mortality across daily categories of standing and physical activity in 16,586 men and women 18–90 yr of age, in the Canada Fitness Survey, 1981–1993. The reference group is those who reported standing almost none of the time and were physically inactive (<7.5 MET·h·wk^{-1}). Hazard ratios are adjusted for age (as a continuous variable), sex, smoking (former, current, nonsmoker), alcohol consumption (abstainer, <10 drinks per month, 10–50 drinks per month, >50 drinks per month), and the Physical Activity Readiness Questionnaire (pass/fail/missing).

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standing more during the day. Arguably, these benefits are observed at the low end of the energy expenditure continuum; however, there was a clear dose–response association observed, such that individuals standing for most of the day had a 33% lower risk of all-cause mortality compared to those who reported standing almost none of the time.

A previous study in this cohort demonstrated a significant positive association between daily sitting time and mortality (20). Thus, it is of interest to explore the relationship between sitting and standing in the sample. The correlation (Spearman ρ) between sitting and standing is -0.52 ($P < 0.0001$), indicating that there is a moderate negative association between these two variables. Further, while most of the sample reported intermediate levels of sitting and standing, 6.7% reported sitting almost all of the time and standing almost none of the time and 2.9% of the sample reported standing almost all of the time and sitting almost none of the time. Thus, although there is a relationship between sitting and standing, standing does not seem to simply be the inverse of sitting, as other factors such as activities of daily living and leisure-time MVPA come into play as alternatives to sitting.

There are several potential mechanisms to explain the observed association between standing and a reduced risk of mortality. For example, the removal of intermittent standing and ambulation in rats by hind limb suspension results in decreases in lipoprotein lipase activity (the enzyme responsible for hydrolysis of triglyceride-rich lipoproteins), triglyceride uptake into red skeletal muscle, and reductions in HDL cholesterol (3). In addition, standing could also disrupt the reductions in shear stress in the lower limbs, which occurs during sitting, which in turn could lead to improved endothelial function (36). However, despite the potential health benefits associated with breaking up periods of sitting, standing for extended periods is not without potential health consequences. For example, studies of prolonged standing in occupational settings have documented psychological and muscle fatigue (11) as well as an increased risk for circulatory problems such as varicose veins (38). Thus, given the evidence accumulated to date, excessive periods of standing may lead to health problems in some individuals. Further research comparing the health effects associated with different durations and patterns of daily standing is required.

There are several strengths and limitations of this study that warrant discussion. The major strengths of the study include its longitudinal, prospective research design and the large representative population sample. However, the baseline data were collected in 1981 with follow-up through 1993. Thus, the degree to which the cohort represents a modern Canadian population in not known. For example, the cohort had a relatively low prevalence of obesity at baseline (21), and substantial increases in body mass index have been observed over the last few decades in Canada (9). The data linkage with the Canadian Mortality Database is also a marked strength of the study design. This study relied on self-reported data for the primary exposure variable (standing) and covariates. The rather crude questionnaire assessment of standing time used in this study should be refined for future studies. Single-item questions about sitting time tend to underestimate total sitting time relative to domain-specific approaches (16), and similar issues may exist with single-item questions about standing. Unfortunately, the level of activity while "standing" was not known in this study, and some people may have been more active than others during their reported standing time. Further, future studies should attempt to measure the entire continuum of human movement more objectively using monitoring equipment (e.g., accelerometers and postural allocation devices) that can partition standing from other behaviors. Unfortunately, baseline data on existing medical conditions were not available; however, the inclusion of the PAR-Q as a covariate and the sensitivity analysis in which deaths occurring within the first year of follow-up were excluded helped to address this limitation. Furthermore, the lack of dietary intake and occupational data in this cohort is another limitation. Finally, because only baseline measurements were used, it is unclear what changes in lifestyle factors may have occurred over the follow-up period and how these changes influenced the observed relationships.

Emerging evidence suggests that excessive sitting is an important risk factor for chronic disease and premature mortality. The results of the present study indicate that greater amounts or standing are related to a lower risk of mortality, suggesting that standing may be a healthier alternative to sitting, particularly among physically inactive individuals.

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The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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