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Sedentary Behaviors Increase Risk of Cardiovascular Disease Mortality in Men

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Abstract

Purpose—To examine the relationship between two sedentary behaviors (riding in car and watching television) and cardiovascular disease (CVD) mortality in men in the Aerobics Center Longitudinal Study.

Methods—Participants were 7,744 men (20-89 yr) initially free of CVD who returned a mail-back survey during 1982. Time spent watching TV and riding in a car were reported. Mortality data were ascertained through the National Death Index till Dec 31, 2003. Cox regression analysis quantified the association between sedentary behaviors (hr/wk watching television, hr/wk riding in car, total hr/wk in these two behaviors) and CVD mortality rates.

Results—377 CVD deaths occurred during 21 years of follow-up. After age-adjustment, time riding in a car and combined time spent in these two sedentary behaviors were positively (*p* trend <.001) associated with CVD death. Men who reported >10 hrs/wk riding in a car or >23 hr/wk of combined sedentary behavior had 82% and 64% greater risk of dying from CVD than those who reported <4 hr/wk or <11 hr/wk, respectively. The pattern of the association did not materially change after multivariate adjustment. Regardless of the amount of sedentary activity reported by these men, being older, normal weight, normotensive, and physically active was associated with a reduced risk of CVD death.

Conclusion—In men, riding in a car and combined time spent in these two sedentary behaviors were significant CVD mortality predictors. Additionally, high levels of physical activity were related to notably lower rates of CVD death even in the presence of high levels of sedentary behavior. Health promotion efforts targeting physically inactive men should emphasize both reducing sedentary activity and increasing regular physical activity for optimal cardiovascular health.

Keywords

Cardiovascular Disease Risk; Sedentary Lifestyle; TV Viewing; Physical Activity

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Introduction

Physical inactivity has become a major public health concern because it is the second leading single cause of death in the United States, trailing only tobacco use (31). Physical inactivity is also associated with increased risk of morbidity or worsening of many chronic diseases and health conditions. Some of these maladies include cardiovascular disease (CVD), congestive heart failure, stroke, certain cancers, osteoporosis, obesity, type 2 diabetes, and hypertension (28).

In 2008, the Physical Activity Guidelines for Americans Advisory Committee concluded that adults should accumulate 150 minutes of moderate intensity physical activity, or 75 minutes of vigorous intensity physical activity, or a combination of both, each week (36). Research has also shown that meeting these guidelines is associated with better CVD risk profiles (13), as well as reduced risk of mortality (29). In 2005, the CDC estimated that 37.7% of the United States population did not participate in the recommended amount of physical activity needed for health benefits, while an additional 14.2% did not participate in more than 10 minutes of moderate or vigorous physical activity throughout the average week (9).

Sedentary pursuits represent a unique aspect of human behavior and should not be viewed as simply the extreme low end of the physical activity continuum. For example, several studies have demonstrated that excess television (TV) viewing time, independent from overall physical activity levels, is adversely associated with metabolic risk factors (18). The effects of extended periods of sedentary behavior in otherwise physically active persons have begun to be elucidated, and they seem to be characterized by metabolic alterations commonly seen in diabetogenic and atherosclerotic profiles (4,18,22,27). However, to date, formal public health recommendations on limiting sedentary behavior have not been developed, although the case for doing so has been recently presented (18).

Dong et al. (14) showed that, on average, adults spend 170 minutes per day watching TV, which accounted for 8.6% of daily total energy expenditure. They also found that time spent driving in the car was the largest contributor to daily total energy expenditure (10.9%; not including sleeping). Furthermore, recent studies using objective measures of physical activity observed that adults spent nearly 55-57% of their monitored time, or ≥7.7 hours/day, in sedentary behaviors (21,30). Nonetheless, few studies have linked sedentary behaviors, such as riding in a car and watching TV, to CVD mortality.

Because a large proportion of daily time is spent in sedentary activities, and extended periods of sedentary behavior are associated with adverse metabolic profiles (4,18,21,22), more research is needed on the public health impact of various sedentary behaviors. We, therefore, examined the relationship between two common sedentary behaviors (i.e., riding in a car and watching TV) and CVD mortality in over 7,700 men from the Aerobics Center Longitudinal Study (ACLS).

Methods

Participants

The data for this study were obtained from the ACLS, a cohort study investigating the influence of physical activity on health outcomes among healthy adults at the Cooper Clinic (Dallas, TX). Potential participants were mailed the 1982 survey. A total of 11,972 individuals returned the 1982 survey. After deceased subjects and incorrect addresses were taken into account, the response rate of this survey was 77%. Participants were not included in the present study if, at baseline, they had incomplete data on the two sedentary behaviors

(n=529); they reported a history of myocardial infarction (n=560), stroke (n=73), or cancer (n=476); they had missing data on age (n=313) or gender (n=192); or they were women (n=2085). These criteria resulted in 7,744 men for analysis. Participants were self- or employer-referred to the clinic for various services such as preventive medical examinations and health, nutrition, and exercise counseling. Most participants were Caucasian from middle or upper socioeconomic strata. All participants provided written consent to participate in the follow-up study. The Cooper Institute Institutional Review Board annually reviewed and approved the study protocol. Additional details of the ACLS methods have been described previously (5,6).

Sedentary behaviors

During the 1982 survey, participants were asked to report their average time (hours per week) viewing TV and riding in a car. We computed combined sedentary behavior in hours per week engaged in these two behaviors. Combined sedentary behavior was the primary exposure, and time viewing TV and time riding in a car were secondary exposures. We classified participants according to categories of sedentary behavior time. Primary and secondary exposures were categorized into quartiles.

Covariates

Age (years) and height (inches; 1 inch=0.025 m) and weight (pounds; 1 pound = 0.45 kg) were self-reported. Body mass index (BMI) was dichotomized as less than 25 (normal) and 25 or greater (overweight/obese). Physically inactive/active was assessed by questions asking the participant to rate their physical activity level (including both leisure and work activities) as compared to others of the same age and sex. Those who answered “extremely inactive”, “inactive”, or “somewhat inactive” were classified as physically inactive, while others who reported “about average”, “somewhat active”, “active”, or extremely active” were classified physically active. Hypertension was defined as a history of physician diagnosis or taking high blood pressure medicine. Diabetes was defined as a history of physician diagnosis or taking insulin. Hypercholesterolemia was defined as a history of physician diagnosis. Other covariates included smoking, alcohol intake (drinks/day), and family history of CVD.

Mortality surveillance

All participants were followed from the date of their return survey until their date of death or December 31, 2003. The National Death Index (NDI) was the primary data source for mortality surveillance, augmented with death certificates. The underlying cause of death was determined from the NDI report or by a nosologist’s review of official death certificates obtained from the department of vital records in the decedent’s state of residence. CVD mortality was defined by *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes 390 to 449.9 before 1999 and *Tenth Revision* (*ICD-10*) codes I00 to I78 during 1999-2003.

Statistical analyses

Baseline characteristics of the population were estimated by vital status. Differences in covariates were tested using Student *t* tests and chi-square tests. We conducted a multivariable Cox regression analysis to evaluate the association between sedentary behavior and CVD mortality. Hazard ratios (HRs), 95% confidence intervals (CIs), and CVD mortality rates (deaths per 10,000 person-years of follow-up) were estimated by comparing each category of sedentary behavior to the lowest category. Multivariable analyses included controls for baseline measures: age (in years), physically inactive (yes or no), smoking status (current smoker or not), alcohol intake (<1, 1-2, and >2 drinks/day),

BMI (kg/m^2), hypertension (yes or no), diabetes (yes or not), hypercholesterolemia (yes or no), and family history of CVD (yes or no). We assessed linear trends in the association of sedentary behavior with the mortality risk by entering into the models the ordinal score of each exposure, and treating this variable as continuous. Cumulative hazard plots grouped by exposure suggested no appreciable violations of the proportional hazards assumption.

We repeated the analyses after stratifying by age, baseline BMI, physical activity, and hypertension status, to assess effects within subgroups. All *P* values were calculated assuming 2-sided alternative hypotheses; *P* values <0.05 were taken to indicate statistically significant comparisons. All analyses were performed using SAS statistical software, version 9.1 (SAS Inc., Cary, NC).

Results

There were 7,744 participants in the study, of which 377 experienced fatal CVD during 21 years of follow-up. Comparisons of baseline characteristics of men who did and did not experience fatal CVD are presented in Table 1. Men who did not die from CVD, for the most part, were younger, had higher than high school education, and had lower BMI compared to men who experienced CVD deaths. Men who did not die from CVD also had a more favorable CVD risk profile (e.g., less likely to have risk factors such as hypertension, diabetes, hypercholesterolemia, and family history of CVD).

As seen in Table 1, there was no significant difference between the two groups for time reported riding in a car ($p_{\text{trend}} = 0.06$). However, time spent viewing TV, 9.1 ± 7.6 h/wk vs. 10.0 ± 7.4 h/wk, was significantly different between the non-CVD death and the CVD death groups, respectively ($p = 0.04$). After combining both sedentary behaviors, there was a significant difference observed between groups ($p = 0.009$); 17.7 ± 10.6 h/wk vs. 19.1 ± 10.3 h/wk in the non-CVD death and CVD death groups, respectively.

Table 2 presents the association between sedentary behaviors and CVD mortality in men. Sedentary behaviors were grouped into quartiles of hours spent engaged in that behavior; higher quartiles represented more sedentary hours. After adjusting for age, a positive gradient of CVD mortality risk was observed across incremental quartiles of riding in a car ($p_{\text{trend}} <0.0001$), and combined sedentary behavior ($p_{\text{trend}} = 0.0002$), but not in watching TV ($p_{\text{trend}} = 0.07$). The direct association between car riding, combining sedentary behavior and CVD mortality remained significant after further adjusting for current smoking, alcohol intake, family history of CVD, BMI, hypertension, diabetes, hypercholesterolemia, and physical inactivity across time spent riding in a car ($p_{\text{trend}} = 0.01$) and combined sedentary behavior ($p_{\text{trend}} = 0.04$). Participants who reported >10 hours/week riding in a car had a 50% greater risk of dying from CVD than the referent group (reporting <4 hours/week) after adjusting for multiple variables. After combining the reported hours of sedentary behavior, participants who reported >23 hours/week of sedentary behavior had a 37% greater risk of CVD mortality, compared to individuals who reported <11 hours/week. Excluding the first year of follow-up did not materially change the magnitude or pattern of the associations observed. To investigate the bias due to the reverse causation between the exposures and CVD mortality, we stratified data by follow-up time (0-10, 11-15, and 15+ years). The associations between time watching TV and CVD mortality were consistent across the follow-up period. The associations between riding in the car and combined sedentary behavior and CVD mortality were variable; however, the overall patterns of the associations were similar compared with the main findings displayed in Table 2.

Figure 1 illustrates the multivariate-adjusted HR and 95% CI by quartiles of time in riding in a car across groups according to age (1A), BMI (1B), physical activity category (1C), and

hypertension status (1D). HRs were significantly associated with the time spent riding in a car within stratum of being younger (<60 years old, $p_{trend} = 0.0009$), overweight (BMI ≥ 25, $p_{trend} = 0.004$), physically inactive ($p_{trend} = 0.02$), and hypertensive ($p_{trend} = 0.03$). A similar pattern of association was observed with time spent in combined sedentary behavior.

Discussion

The objective of this study was to assess the association of two common sedentary behaviors, riding in a car and watching TV, with CVD mortality in men. In age-adjusted analysis, TV watching, riding in a car and combined sedentary behavior were significantly associated with risk of CVD mortality. However, multivariate-adjusted analysis resulted in no association of time watching TV and CVD mortality risk. Riding in a car (>10 hrs/wk) and combined sedentary behavior (>23 hrs/wk) remained significantly associated with 48% and 37% increased risk of CVD mortality, respectively, as compared with the referent groups (<4 hrs/wk and <11 hrs/wk). Results further showed, regardless of time spent in riding in a car or in combined sedentary behavior, being older, normal weight, normotensive, and physically active were associated with a lower risk of CVD mortality in this cohort.

Beginning in the 1950s, physical inactivity was reported to be associated with atherosclerosis (32,33). Since that time, evidence has accumulated linking physical inactivity to incident CVD (1,2,17,28,29). Emerging physical inactivity research assesses the role of various sedentary behaviors. During the last decade, numerous epidemiological studies have shown indicators of physical inactivity, such as TV viewing, driving in a car and sitting, are strongly related to the risk for developing dyslipidemia (1,2), obesity (24,26), type 2 diabetes (21,23,24), hypertension (3,26), metabolic syndrome (18), and CVD (2,3,7,18,24,26). Limited studies have also revealed that sedentary behavior may increase the risk for CVD mortality (24,26,27). Despite these findings, to date there are no public health recommendations for adults regarding the amount of time an individual should spend engaged in sedentary behaviors (19).

Very few studies have assessed the independent association of time spent riding in a vehicle and CVD mortality. Some of the early work on this topic by Morris and colleagues (32) showed a positive relationship between men with sedentary occupations and the incidence of CVD mortality. In that study, London bus drivers were 1.8 times more likely than bus conductors to develop coronary heart disease (32). Actual time spent driving a bus was not assessed; however, it can be assumed that bus drivers spent more weekly hours driving compared to bus conductors. The present study indicated that riding in a car >10 hours/week increased CVD mortality risk by 48%. Further research in diverse groups of men and women are needed to clarify the relationship between hours spent riding in a car and risk of CVD mortality.

Research suggests that, on average, adults are quite sedentary spending ≥7.7 hours/day involved in activities resulting in very low energy expenditure (8,21,30). Recent reports estimate that more than 60% of American adults are not regularly active, and 25% of the adult population is physically inactive (9). More recently, it was reported that a large percentage of daily energy expenditure comes from sedentary behaviors and leisure time activities. Dong et al. (14) reported driving a car and TV watching as the second and fourth largest contributors to daily energy expenditure, respectively. Despite no other studies relating total sedentary behavior to CVD risk factors, incidence, or mortality having been published, our results, combined with previous findings, indicate that decreasing time spent in total sedentary behavior may increase overall physical activity and energy expenditure and, therefore, decrease the risk of CVD mortality.

Another major finding of our study was that, for any given amount of time spent riding in a car, men who were physically active (Figure 1-C) maintained lower CVD mortality rates than men who were classified as physically inactive. Research indicates that physical activity is protective against CVD mortality (16), and that less-active individuals have a greater associated risk of obesity (7, 18, 24, 37), hypertension (3), diabetes (18, 24), and some forms of cancer (20), thus resulting in increased mortality (15, 17, 25). Previous ACLS reports have shown that being aerobically unfit due to insufficient amounts of regular physical activity is an independent predictor of mortality and nonfatal disease (34, 35). In addition, other evidence indicates that higher levels of aerobic fitness, a strong indicator of a person's recent level of physical activity, is protective against all-cause and CVD mortality in men in the presence of overweight and obesity (37), type 2 diabetes (10, 11), and hypertension (12). One other study of sedentary behavior determined that physically active men and women had lower rates of CVD mortality in the presence of elevated time spent sitting (27). The current study's findings add to the cumulative evidence for the benefits of being physically active despite the presence of other potentially health-diminishing behaviors and conditions.

A growing body of research is beginning to elucidate the mechanistic pathways that contribute to the health risks associated with sedentary behaviors. Some of the mechanisms may include adverse alterations to cardiac function, glucose homeostasis, and lipid metabolism (4,18,21,27). Recent findings suggest that physiologic mechanisms associated with excessive sedentary behavior are different than the physiologic benefits of regular exercise (18). This may help to partially explain the elevated risk of CVD mortality noted in physically active men who also demonstrated high levels of total sedentary behavior in the current study. Additional research to ascertain the pathophysiologic mechanisms associated with total and segmented components of sedentary behavior is well warranted.

This study had several strengths. The relatively long follow-up (21 years) was sufficient to accumulate enough fatal end-points to assess the association of sedentary behaviors and CVD mortality. An extensive physical examination also provided detailed information on the absence or presence of medical conditions and CVD risk factors. The limitations of the study include the representativeness of the study cohort, which was male, primarily white, well-educated, and in middle to upper socioeconomic status. Thus, results may not be generalized to other populations; however, it should not affect the internal validity, which may be considered a strength. There may be confounding subclinical diseases affecting the outcome of the study. However, the probability of these diseases affecting the relationship between sedentary behavior and CVD mortality is low, especially when considering the extensive baseline medical examination and observing a lack of change in the associations when eliminating participants with CVD events in year one of follow-up. Data were only available at baseline, so changes in the exposure variables during the follow-up period could not be assessed. Although true exposure could have changed significantly within many subjects during follow-up, there was still a remarkably strong relationship between time spent riding in a car and CVD mortality. This source of error likely led to an underestimation of the full magnitude of sedentary behavior upon the risk of CVD mortality. The status of being physically inactive or active was self-reported with a very crude assessment and could have resulted in some misclassification. Finally, we do not have sufficient data on diet and medication usage to include in the analytic models. Despite these limitations, the results revealed a strong association between self-reported sedentary behaviors and CVD mortality risk.

The magnitude of the association between combined sedentary behavior and CVD mortality observed in this study is clinically relevant. In this prospective study of 7,744 men, participants were at significantly greater risk of CVD mortality if they reported riding in a

car >10 hours/week or participated in >23 hours/week of combined sedentary behaviors. Therefore, we suggest that men, in combination with increasing their level of physical activity, also reduce sedentary behavior to diminish their risk of CVD mortality. This study provides further evidence that formal recommendations on limiting sedentary behavior in persons of varying age should be developed to provide public health professionals and clinical practitioners with information to improve their effectiveness in promoting physical activity and health (19).

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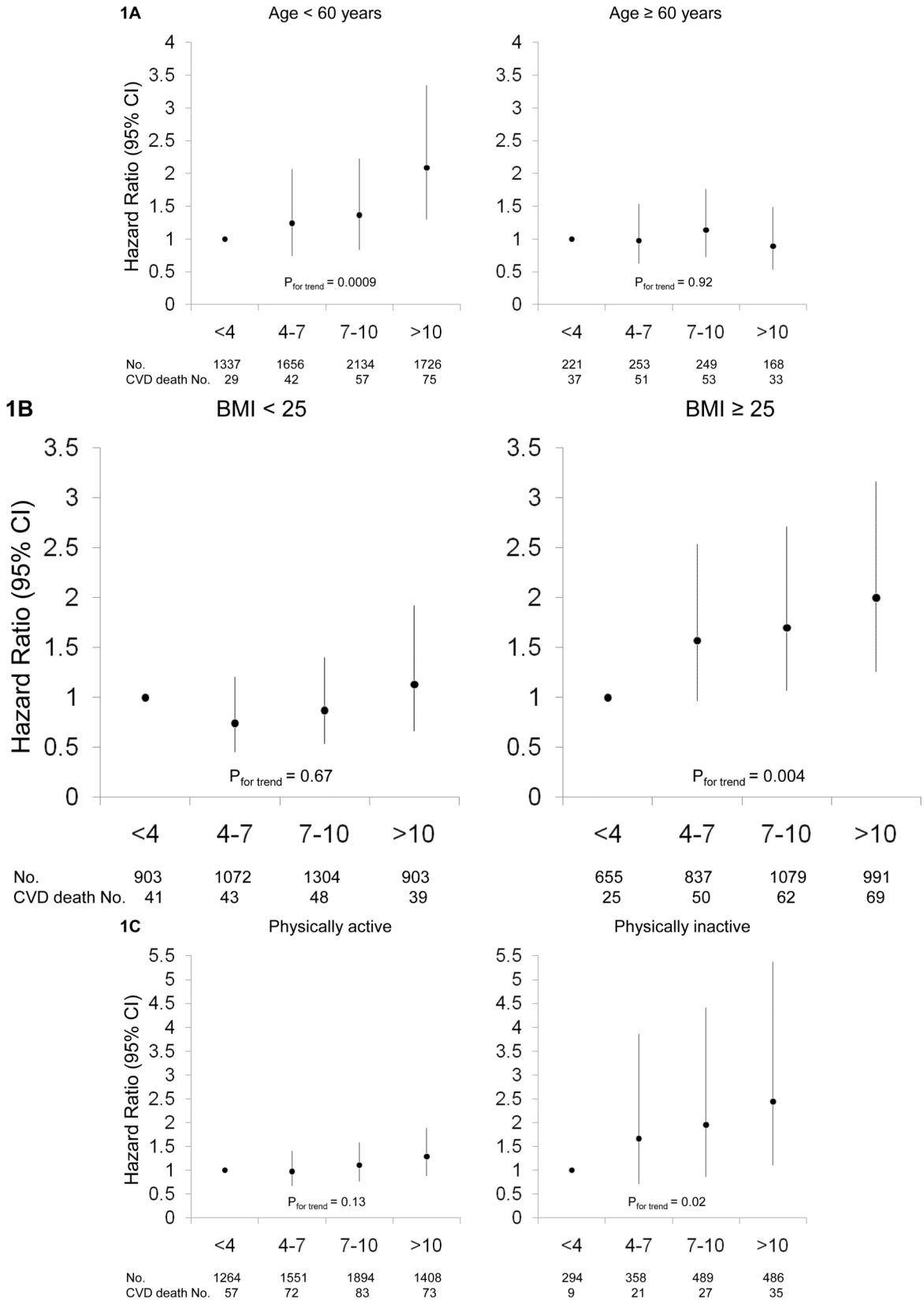

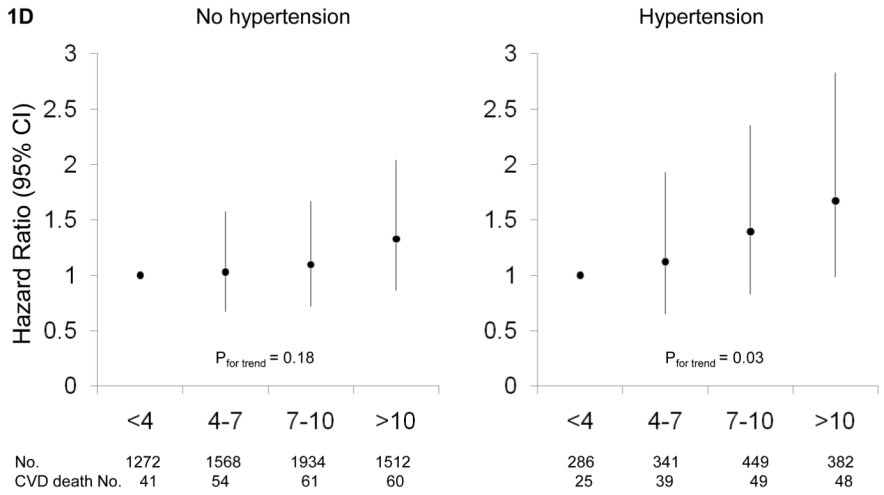

FIGURE 1.

Multivariate*-adjusted hazard ratio and 95% confidence intervals (CI) by quartiles of time spending in riding in a car across **(1A)** age groups, **(1B)** body mass index (BMI) groups, **(1C)** physical activity categories, and **(1D)** hypertension status in 7744 men. *adjusted by age, current smoker, alcohol intake (<1, 1-2, and >2 drinks/day), family history of cardiovascular disease, diabetes, hypercholestromia, and each of other variables in the figures. Likelihood ratio test for interaction, $\chi^2_{df=1} = 3.21$, $P = 0.07$, for age-riding in a car; $\chi^2_{df=1} = 3.67$, $P = 0.055$, for BMI-riding in a car; $\chi^2_{df=1} = 2.53$, $P = 0.11$, for physically inactive-riding in a car; and $\chi^2_{df=1} = 0.24$, $P = 0.62$ for hypertension-riding in car.

TABLE 1

Baseline characteristics of study participants by vital status during follow-up

Characteristic	All (n= 7,744) (mean (SD) or N (%))	Men who did not die from CVD (n = 7,367) (mean (SD) or N(%))	Men who died from CVD (n = 377) (mean (SD) or N(%))	P value
Age (years)	47.1 (10.1)	46.5 (9.8)	57.5 (10.4)	<0.0001
Black (%)	42 (0.5)	40 (0.5)	2 (0.5)	1.0
High school or less education (%)	344 (4.4)	308 (4.2)	36 (9.6)	<0.0001
Body mass index (kg/m^2)	25.5 (3.2)	25.5 (3.2)	26.6 (3.8)	0.009
Physically inactive* (%)	1,627 (21.0)	1,535 (20.8)	92 (24.4)	0.1
Riding in the car (h/wk)	8.5 (6.4)	8.5 (6.4)	9.2 (6.7)	0.06
Watching TV (h/wk)	9.2 (7.6)	9.1 (7.6)	10.0 (7.4)	0.04
Combined sedentary behavior (h/wk)	17.7 (10.5)	17.7 (10.6)	19.1 (10.3)	0.009
Current smoker (%)	816 (10.5)	755 (10.3)	61 (16.2)	0.0003
Alcohol intake (drinks/day) † (%)				0.09
<1	4853 (62.7)	4597 (62.4)	256 (67.9)	
1-2	1714 (22.1)	1645 (22.3)	69 (18.3)	
>2	1177 (15.2)	1125 (15.3)	52 (13.8)	
Abnormal ECG (%)	470 (6.4)	439 (6.2)	31 (8.7)	0.07
Hypertension‡ (%)	1,458 (18.8)	1,297 (17.6)	161 (42.7)	<0.0001
Diabetes§ (%)	186 (6.0)	154 (2.1)	32 (8.5)	<0.0001
Hypercholesterolemia# (%)	465 (6.0)	422 (5.7)	43 (11.4)	<0.0001
Family history of CVD (%)	1,961 (25.3)	1,832 (24.9)	129 (34.2)	<0.0001

SD, standard deviation; METs, maximal metabolic equivalents; ECG, electrocardiogram; CVD, cardiovascular disease.

*Physically inactive is defined as reporting extremely inactive, inactive, or somewhat inactive from 1982 survey.

†One unit of alcohol is defined as 12 ounces (3.41 dL) of beer, 5 ounces (1.421 dL) of wine, or 1.5 ounces (0.4262 dL) of hard liquor.

‡Hypertension is defined as a history of physician diagnosis or taking high blood pressure medicine.

§Diabetes is defined as a history of physician diagnosis or taking insulin.

#Hypercholesterolemia is defined as a history of physician diagnosis.

TABLE 2

Hazard ratios (95% confidence intervals) of CVD mortality according to quartiles of sedentary behaviors

	Quartiles of sedentary behavior				
	1 (lowest)	**2**	**3**	**4**	**P for trend**
Riding in a car (h/wk)					
Range	<4	4-7	7-10	>10	
Cases	66	93	110	108	
N	1558	1909	2383	1894	
Age- adjusted HR (95% CI)	1	1.14 (0.83-1.57)	1.33 (0.98-1.80)	1.82 (1.34-2.47)	<0.0001
Multivariate HR (95% CI)*	1	1.09 (0.78-1.52)	1.23 (0.89-1.70)	1.50 (1.08-2.09)	0.01
Watching TV (h/wk)					
Range	<4	4-8	8-12	>12	
Cases	67	115	95	100	
N	1795	2473	1611	1865	
Age- adjusted HR (95% CI)	1	1.20 (0.89-1.62)	1.56 (1.14-2.13)	1.27 (0.93-1.73)	0.07
Multivariate HR (95% CI)*	1	1.02 (0.74-1.42)	1.27 (0.90-1.78)	0.96 (0.68-1.36)	0.94
Combined sedentary behavior (h/wk)					
Range	<11	11-15	16-23	>23	
Cases	77	70	122	108	
N	2011	1689	2211	1833	
Age- adjusted HR (95% CI)	1	1.18 (0.85-1.63)	1.53 (1.15-2.03)	1.64 (1.23-2.20)	0.0002
Multivariate HR (95% CI)*	1	1.09 (0.77-1.54)	1.33 (0.96-1.83)	1.37 (1.01-1.87)	0.04

*Adjusted for age, physically inactive, current smoker, alcohol intake (<1, 1-2, and >2 drinks/day), body mass index, family history of CVD, hypertension, diabetes, and hypercholestromia.