Table 3 HRs for All-Cause Mortality and CVD Events With Other Exclusions*

Screen Time	Cases/Events	HR (95% CI) Model 1†	Model 2‡	Model 3§
All-cause mortality				
<2 h/day	742/35	1.00	1.00	1.00
≥2–<4 h/day	1,204/97	1.11 (0.77–1.61)	1.11 (0.77–1.61)	1.14 (0.78–1.65)
≥4 h/day	1,204/115	1.81 (1.26–2.60)	1.57 (1.09–2.28)	1.54 (1.06–2.24)
Trend p value		<0.001	0.008	0.017
CVD events				
<2 h/day	696/14	1.00	1.00	1.00
≥2–<4 h/day	2,176/84	1.95 (1.08–3.50)	1.97 (1.09–3.57)	1.98 (1.09–3.59)
≥4 h/day	1,072/65	2.56 (1.41–4.65)	2.14 (1.16–3.94)	2.10 (1.14–3.88)
Trend p value		0.007	0.047	0.052

*Excluding previous events, cancer registration before baseline, and events during the first year of follow-up, for screen-based entertainment groups (compared with the referent <2 h/day screen-based entertainment group). †Model 1 covariables: age, sex; ‡Model 2: plus body mass index, smoking, marital status, ethnicity, social class, long-standing illness, occupational physical activity, doctor-diagnosed diabetes and hypertension; §Model 3: plus moderate to vigorous physical activity.
Abbreviations as in Table 2.

activity: HR: 1.0010, 95% CI: 1.0002 to 1.0018, $p = 0.02$) and all-cause mortality (age- and sex-adjusted HR: 1.0018; 95% CI: 1.0013 to 1.0024, $p < 0.001$; fully adjusted including physical activity: HR: 1.0011, 95% CI: 1.0005 to 1.0017, $p < 0.001$). Repeating the same analysis with physical activity as the main exposure showed that the protective effect of physical activity on all-cause mortality is independent of screen time (nonscreen time covariable-adjusted HR: 0.9912; 95% CI: 0.9862 to 0.9962, $p = 0.001$; fully adjusted including screen time: HR: 0.9919, 95% CI: 0.9870 to 0.9968, $p = 0.001$). The inclusion of screen time weakened the association between physical activity and CVD events (nonscreen time covariable-adjusted HR: 0.9956; 95% CI: 0.9913 to 0.9998, $p = 0.041$; fully adjusted including screen time: HR: 0.9960, 95% CI: 0.9918 to 1.003, $p = 0.07$).

Online Table 1 presents analyses stratified by physical activity and other key risk factors. Although the statistical power in certain strata was low due to low number of events, effect estimates were markedly consistent in direction. There was little evidence for an association between screen time and CVD events among those who reported long-standing illness (n = 2,234; 158 CVD events): fully adjusted HR for ≥4 h/day: 1.70, 95% CI: 0.94 to 3.09, $p = 0.15$. Despite the small number of events among those with no long-standing illness (n = 2,016, 55 CVD events) and the corresponding wide CIs, there was some evidence for an association: HR for ≥4 h/day: 6.51, 95% CI: 1.47 to 28.8, $p = 0.046$).

Explanatory analysis. A total of 1,928 cases had valid data in all 4 potentially mediating variables (BMI, CRP, total cholesterol, HDL cholesterol), corresponding to 70 CVD events, and were entered in the explanatory analysis. Compared with those excluded, those included had lower mean age, higher physical activity ($p = 0.002$), and lower screen time ($p = 0.001$) and were more likely to be married ($p = 0.02$), have a BMI over 30 kg/m^2, have a long-standing illness ($p < 0.001$), be inactive at work ($p < 0.001$), not to have been diagnosed with hypertension ($p < 0.001$), not to have had a CVD event ($p < 0.001$), and to have met the physical activity recommendations ($p < 0.001$) (data not shown). Figure 1 presents the extent to which BMI, HDL and total cholesterol, and CRP explain the associations between screen time and CVD events. CRP explained CVD events to the greatest extent (18%), which was equal to the amount explained by the 3 metabolic factors together. These 4 biological factors explained approximately 28% of the screen time–CVD association, with 25% explained by BMI, HDL cholesterol, and CRP. These 3 variables (but not total cholesterol) met the statistical criteria for being a mediator variable (25).

Discussion

Our results suggest that there is an independent, deleterious relationship of screen-based recreational sitting time with CVD events and all-cause mortality. Compared with those spending <2 h/day on screen-based entertainment, there was a 48% increased risk of all-cause mortality in those spending ≥4 h/day and an approximately 125% increase in risk of CVD events in those spending ≥2 h/day (Table 3). These associations were independent of traditional risk factors such as smoking, hypertension, BMI, social class, as well as physical activity. Our all-cause mortality results are in agreement with a large study of Canadian adults who were followed up for 12 years, where the all-cause mortality HR for the highest category of nonrecreational (work, school, housework) daily sitting time ("almost all the time") was 1.54 (26). Another study among >8,000 Australian adults reported a very similar all-cause mortality HR (1.46) for ≥4 h of TV watching compared with the <2 h/day reference group (23). Both studies were also robust for adjustments or stratifications by sex, physical activity level, smoking, and BMI. The Canadian study, however, had minimal control of physical health at baseline, which makes reverse causation a strong possibility (26). In contrast, we

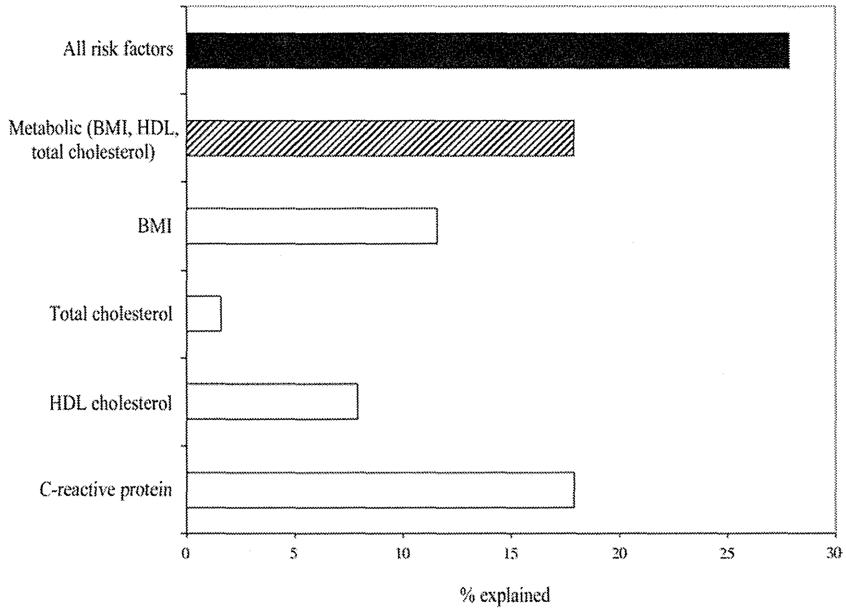

Figure 1 **Extent to Which Biological Risk Factors Explain Association Between Screen-Based Entertainment Time and Cardiovascular Events**

n = 1,928 with valid data on all 4 risk factors. BMI = body mass index; HDL = high-density lipoprotein.

were able to exclude respondents with objectively verified CVD/cancer at baseline and adjust for multiple indicators of health. Our study specifically examined recreational sedentary time. Because the largest proportion of sitting time for many people is spent at work and in many circumstances is difficult to modify, our data imply that reduced recreational sitting time might be linked to reduced risk. Although we found no evidence of a dose-response relationship, our analysis suggests that a threshold of ≥2 h/day of screen time might be linked to an increased risk for a CVD event. The Australian study (23) found that daily TV viewing times in excess of 4 h/day (but not 2 to 4 h/day) were associated with CVD death risk. We speculate that this disagreement occurs because our exposure variable was more inclusive than TV alone that was used in the Australian study and because our CVD outcome included nonfatal as well as fatal events. We were not able to demonstrate, in contrast to the Canadian (26) study, a clear relationship between screen time and CVD events among those who meet the physical activity recommendations and among those with a BMI <25 kg/m^2 (Online Table 1). In this analysis, there were only 50 events, and as such, we speculate that the lack of a robust and statistically important association was due to limited statistical power. Nevertheless, the direction of the association was markedly consistent across all strata, lending support to our main conclusion that screen time is an independent predictor of CVD events. Another large study among U.S. women, Manson et al. (27), found that extreme amounts of sitting (>16 h/day) were linked to an increased risk for incident CVD compared with <4 h/day after 6 years of follow-up. Such levels of sitting imply that an individual spends their entire waking time sitting, but there was no evidence for adverse effects of smaller amounts of daily sitting (27).

Biological mediators. The precise pathways linking sitting and cardio-metabolic disease are unclear. It has been suggested that metabolic mechanisms might partly explain these links (15), and data from animals have demonstrated that prolonged sitting might disturb lipid metabolism. There is evidence for a dramatic reduction of lipoprotein lipase activity (by 80% to 90%) during sitting compared with standing up or ambulating (28). Lipoprotein lipase is a key enzyme for the catabolism of triglyceride-rich lipoproteins in the endothelium, and its reduced activity might raise the possibility of other metabolic actions being impaired (15). Our study provides novel findings to suggest a role of metabolic and inflammatory pathways in partly explaining the association between sitting and CVD risk. A well-established marker of low-grade inflammation, CRP, was approximately 3-fold higher in participants spending more than 4 h/day in screen time and explained a substantial amount of the screen time–CVD association. Because screen time was assessed at the same time point as the risk markers, we cannot establish the nature of the temporal relationship between these factors. Nevertheless, our results are in concordance with another study of ours with clear temporal element, which found that TV viewing at age 23 years was independently associated with composite factors of metabolic (including HDL and BMI) and hemostatic/inflammatory (including CRP) but not with cholesterol (total or LDL) biomarkers at 42 years (29) (Stamatakis et al., unpublished observations, January to February, 2010). Both sets of our results are partly corroborated by experimental data in humans. The induction of 5 days bed rest, which represents an extreme form of sedentary behavior, had profound effects on various metabolic risk (including insulin resistance and vascular dysfunction) but not on inflammation (30). Thus, low-grade inflammation might only result from chronic exposure to sedentary lifestyle. A further important mechanism might be related to a decreased expression of endothelial nitric oxide synthase that is caused from reduced local shear stress as a result of lower blood flow from excessive sitting. Further experimental studies will be required to determine the exact mechanisms accounting for increased CVD risk during prolonged inactivity in humans.

Strengths. The main strengths of this study are the detailed measures we were able to take to minimize reverse causality, the many potential confounders we included in our models, and the objectively confirmed CVD events. Other strengths include the nationally representative sample that is expected to have adequate variability in terms of primary and secondary exposures, and therefore it is appropriate to examine the relationships of interest.

Study limitations. Screen time was self-reported. The TV and computer use questions have been shown to underestimate sedentary time when compared with accelerometry (31). Although we have no information on the reliability and criterion validity of the SHS03 screen time questions, we observed the expected associations of screen time with various sociodemographic variables, which provides convergent validity evidence of the screen time data. It is also encouraging that a recent review (7) concluded that TV and computer use time questions have the strongest reliability and validity among sitting-related questions. Although screen time is a partial indicator of overall sitting, TV and computer use account for the overwhelming proportion of leisure time sitting among British adults (32). Also, screen entertainment time tends to be associated with excess calorie consumption, but we were unable to account for dietary intake, although our results were independent of BMI. Finally, our explanatory analyses were limited by the small sample size available, due to limited compliance with blood measurements.

Conclusions

We found a deleterious relationship between recreational sitting and all-cause mortality and cardiovascular events. Our analyses suggest the relationship is independent of physical activity, although further studies that employ objective measures of activity and sedentary time are required to confirm this. We also provide evidence to suggest a role of metabolic and inflammatory pathways in partly explaining the association between sitting and CVD risk. Further experimental studies will be required to determine the exact mechanisms. Our results support the inclusion of a sedentary behavior guideline in public health recommendations for CVD prevention.

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Key Words: mortality ■ physical activity ■ sedentary behavior.

APPENDIX

For a supplementary table, please see the online version of this article.

論文名	Screen-based entertainment time, all-cause mortality, and cardiovascular events: population-based study with ongoing mortality and hospital events follow-up
著 者	Stamatakis E, Hamer M, Dunstan DW
雑誌名	J Am Coll Cardiol
巻・号・頁	57 (3)　　292-299
発行年	2011
PubMedリンク	http://www.ncbi.nlm.nih.gov/pubmed/21232666

対象の内訳		ヒト	動物	地 域	欧米	研究の種類	縦断研究
	対象	一般健常者	空白		(　)		コホート研究
	性別	男女混合	(　)		(　)		(　)
	年齢	35歳以上	[redacted]		(　)		前向き研究
	対象数	1000～5000			(　)		(　)
調査の方法	質問紙	(　)					

アウトカム							
	予 防	心疾患予防	な し	な し	な し	死亡	(　)
	維持・改善	な し	な し	な し	な し	(　)	(　)

図 表

Table 2 HRs for All-Cause Mortality and CVD Events for Screen-Based Entertainment Groups* Excluding Previous CVD Hospital Stays

	Cases/Events	HR (95% CI) Model 1†	Model 2‡	Model 3§
All-cause mortality				
<2 h/day	791/42	1.00	1.00	1.00
≥2–<4 h/day	2,492/138	1.13 (0.080–1.60)	1.12 (0.79–1.58)	1.14 (0.80–1.62)
≥4 h/day	1,311/146	1.77 (1.25–2.50)	1.52 (1.06–2.16)	1.48 (1.04–2.13)
Trend p value		<0.001	0.013	0.029
CVD events				
<2 h/day	745/18	1.00	1.00	1.00
≥2–<4 h/day	2,333/115	2.20 (1.30–3.71)	2.22 (1.32–3.77)	2.23 (1.31–3.80)
≥4 h/day	1,172/86	2.78 (1.62–7.70)	2.30 (1.33–3.96)	2.25 (1.30–3.89)
Trend p value		0.001	0.009	0.010

*Compared with the referent <2 h/day screen-based entertainment group. †Model 1 covariables: age, sex; ‡Model 2: plus body mass index, smoking, marital status, ethnicity, social class, long-standing illness, occupational physical activity, doctor-diagnosed diabetes and hypertension; §Model 3: plus moderate-to-vigorous physical activity.
CI = confidence interval; CVD = cardiovascular disease; HR = hazard ratio.

Table 3 HRs for All-Cause Mortality and CVD Events With Other Exclusions*

Screen Time	Cases/Events	HR (95% CI) Model 1†	Model 2‡	Model 3§
All-cause mortality				
<2 h/day	742/35	1.00	1.00	1.00
≥2–<4 h/day	1,204/97	1.11 (0.77–1.61)	1.11 (0.77–1.61)	1.14 (0.78–1.65)
≥4 h/day	1,204/115	1.81 (1.26–2.60)	1.57 (1.09–2.26)	1.54 (1.06–2.24)
Trend p value		<0.001	0.008	0.017
CVD events				
<2 h/day	696/14	1.00	1.00	1.00
≥2–<4 h/day	2,176/84	1.95 (1.08–3.50)	1.97 (1.09–3.57)	1.98 (1.09–3.59)
≥4 h/day	1,072/65	2.56 (1.41–4.65)	2.14 (1.16–3.94)	2.10 (1.14–3.88)
Trend p value		0.007	0.047	0.052

*Excluding previous events, cancer registration before baseline, and events during the first year of follow-up, for screen-based entertainment groups (compared with the referent <2 h/day screen-based entertainment group). †Model 1 covariables: age, sex; ‡Model 2: plus body mass index, smoking, marital status, ethnicity, social class, long-standing illness, occupational physical activity, doctor-diagnosed diabetes and hypertension; §Model 3: plus moderate to vigorous physical activity.
Abbreviations as in Table 2.

図表掲載箇所	P295, Table2, P296, Table3
概 要 (800字まで)	本研究は、2003Scottish Health Surveyに参加した35歳以上の男女4,512名を対象に2007年まで追跡調査を行い、余暇時間中のテレビ視聴やビデオゲーム等のスクリーンタイムと総死亡および心血管疾患発症/死亡の関連について検討したものである。質問紙によって、余暇時間のスクリーンタイム、仕事中の身体活動量、余暇時間の身体活動量、健康状態などを聞き取った。余暇時間のスクリーンタイムを2時間未満/日、2-4時間/日、4時間以上/日に分類した。2時間未満/日と比較すると、4時間以上/日の者は、総死亡ハザード比が1.52倍(95%信頼区間:1.06-2.16)増加し、心血管疾患発症ハザード比が2.30倍(1.33-3.96)に増加した。中高強度身体活動時間で調整後も、総死亡ハザード比1.48倍(1.04-2.13)、心血管疾患発症ハザード比2.25倍(1.30-3.89)と同様の結果を示した。また、フォローアップ初年度の死亡と発症、がん既往歴のある者を除外した場合でも同様の結果を示した。
結 論 (200字まで)	余暇時間の座位時間(テレビやビデオゲームなど)は、中・高強度の身体活動量に関わらず、総死亡や心血管疾患発症/死亡リスクに関連していた。
エキスパートによるコメント (200字まで)	身体活動基準の策定に用いられた研究の1つである。近年、テレビ視聴時間や座位時間が、死亡や様々な疾患の発症と関連することが報告されている。このような研究が行われることは、テレビ視聴時間や座位時間が長時間に及ぶことを抑制するうえで非常に役立つ研究結果をもたらす。余暇時間の過ごし方は国により大きく異なることが予想され、日本においてもこのような研究が広く行われることが望まれる。

担当者:久保絵里子・村上晴香・宮地元彦

Sedentary Behaviors Increase Risk of Cardiovascular Disease Mortality in Men

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[1]*Department of Exercise Science, Arnold School of Public Health, University of South Carolina, Columbia, SC;* [2]*Prevention Research Center, Arnold School of Public Health, University of South Carolina, Columbia, SC;* [3]*Preventive Medicine Laboratory, Pennington Biomedical Research Center, Baton Rouge, LA; and* [4]*Department of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, Columbia, SC*

BASIC SCIENCES

ABSTRACT

WARREN, T. Y., V. BARRY, S. P. HOOKER, X. SUI, T. S. CHURCH, and S. N. BLAIR. Sedentary Behaviors Increase Risk of Cardiovascular Disease Mortality in Men. *Med. Sci. Sports Exerc.*, Vol. 42, No. 5, pp. 879–885, 2010. **Purpose:** The purpose of this study was to examine the relationship between two sedentary behaviors (riding in a car and watching TV) and cardiovascular disease (CVD) mortality in men in the Aerobics Center Longitudinal Study. **Methods:** Participants were 7744 men (20–89 yr) initially free of CVD who returned a mail-back survey during 1982. Time spent watching TV and time spent riding in a car were reported. Mortality data were ascertained through the National Death Index until December 31, 2003. Cox regression analysis quantified the association between sedentary behaviors (hours per week watching TV, hours per week riding in a car, and total hours per week in these two behaviors) and CVD mortality rates. **Results:** Three hundred and seventy-seven CVD deaths occurred during 21 yr of follow-up. After age adjustment, time riding in a car and combined time spent in these two sedentary behaviors were positively ($P_{trend} < 0.001$) associated with CVD death. Men who reported >10 h·wk^{-1} riding in a car or >23 h·wk^{-1} of combined sedentary behavior had 82% and 64% greater risk of dying from CVD than those who reported <4 or <11 h·wk^{-1}, 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, having normal weight, being normotensive, and being physically active were 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. In addition, 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. **Key Words:** CARDIOVASCULAR DISEASE RISK, SEDENTARY LIFESTYLE, TV VIEWING, PHYSICAL ACTIVITY

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 min of moderate-intensity physical activity or 75 min 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 Centers for Disease Control and Prevention estimated that 37.7% of the U.S. population did not participate in the recommended amount of physical activity needed for health benefits, whereas an additional 14.2% did not participate in more than 10 min 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 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

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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 $min \cdot d^{-1}$ 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 $h \cdot d^{-1}$ 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 7700 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); if they reported a history of myocardial infarction (n = 560), stroke (n = 73), or cancer (n = 476); if they had missing data on age (n = 313) or gender (n = 192); or if they were women (n = 2085). These criteria resulted in 7744 men for analysis. Participants were self-referred 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 ($h \cdot wk^{-1}$) 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 (yr) and height (inches; 1 inch = 0.025 m) and weight (lb; 1 lb = 0.45 kg) were self-reported. Body mass index (BMI) was dichotomized as less than 25 $kg \cdot m^{-2}$ (normal) and 25 $kg \cdot m^{-2}$ or greater (overweight or obese). Physically inactive or active was assessed by questions asking the participant to rate their physical activity level (including both leisure and work activities) as compared with others of the same age and sex. Those who answered "extremely inactive," "inactive," or "somewhat inactive" were classified as physically inactive, whereas 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 per day), and family history of CVD.

Mortality surveillance. All participants were followed from the date of their return survey until the date of their death or until December 31, 2003. The National Death Index was the primary data source for mortality surveillance, augmented with death certificates. The underlying cause of death was determined from the National Death Index 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 the International Classification of Diseases, Ninth Revision codes 390–449.9 before 1999 and the International Classification of Diseases, Tenth Revision 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 (HR), 95% confidence intervals (CI), 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 (yr), physically inactive (yes or no), smoking status (current smoker or not), alcohol intake (less than one, between one and two, and more than two drinks per day), BMI ($kg \cdot m^{-2}$), hypertension (yes or no), diabetes (yes or no), 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.

TABLE 1. Baseline characteristics of study participants by vital status during follow-up.

Characteristic	All (*N* = 7744), mean (SD) or *n* (%)	Men Who Did Not Die from CVD (*n* = 7367), mean (SD) or *n* (%)	Men Who Died from CVD (*n* = 377), mean (SD) or *n* (%)	*P* Value
Age (yr)	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
BMI ($kg \cdot m^{-2}$)	25.5 (3.2)	25.5 (3.2)	26.6 (3.8)	0.009
Physically inactive (%)[a]	1627 (21.0)	1535 (20.8)	92 (24.4)	0.1
Riding in a car ($h \cdot wk^{-1}$)	8.5 (6.4)	8.5 (6.4)	9.2 (6.7)	0.06
Watching TV ($h \cdot wk^{-1}$)	9.2 (7.6)	9.1 (7.6)	10.0 (7.4)	0.04
Combined sedentary behavior ($h \cdot wk^{-1}$)	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 per day) (%)[b]				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 (%)[c]	1458 (18.8)	1297 (17.6)	161 (42.7)	<0.0001
Diabetes (%)[d]	186 (6.0)	154 (2.1)	32 (8.5)	<0.0001
Hypercholesterolemia (%)[e]	465 (6.0)	422 (5.7)	43 (11.4)	<0.0001
Family history of CVD (%)	1961 (25.3)	1832 (24.9)	129 (34.2)	<0.0001

[a] Physically inactive is defined as reporting extremely inactive, inactive, or somewhat inactive from the 1982 survey.
[b] One unit of alcohol is defined as 12 oz (3.41 dL) of beer, 5 oz (1.421 dL) of wine, or 1.5 oz (0.4262 dL) of hard liquor.
[c] Hypertension is defined as a history of physician diagnosis or taking high blood pressure medicine.
[d] Diabetes is defined as a history of physician diagnosis or taking insulin.
[e] Hypercholesterolemia is defined as a history of physician diagnosis.
METs, maximal metabolic equivalents; CVD, cardiovascular disease.

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 two-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 7744 participants in the study, of which 377 experienced fatal CVD during 21 yr 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 with 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_{trend} = 0.06). However, time spent viewing TV, 9.1 ± 7.6 versus 10.0 ± 7.4 $h \cdot wk^{-1}$, 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

TABLE 2. HR (95% CI) of CVD mortality according to quartiles of sedentary behaviors.

	Quartiles of Sedentary Behavior				
	1 (lowest)	2	3	4	P_{trend}
Riding in a car ($h \cdot wk^{-1}$)					
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)[a]	1	1.09 (0.78–1.52)	1.23 (0.89–1.70)	1.50 (1.08–2.09)	0.01
Watching TV ($h \cdot wk^{-1}$)					
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)	
Multivariate HR (95% CI)[a]	1	1.02 (0.74–1.42)	1.27 (0.90–1.78)	0.96 (0.68–1.36)	0.94
Combined sedentary behavior ($h \cdot wk^{-1}$)					
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)[a]	1	1.09 (0.77–1.54)	1.33 (0.96–1.83)	1.37 (1.01–1.87)	0.04

[a] Adjusted for age, physically inactive, current smoker, alcohol intake (less than one, between one and two, and more than two drinks per day), BMI, family history of CVD, hypertension, diabetes, and hypercholesterolemia.

($P = 0.009$): 17.7 ± 10.6 versus 19.1 ± 10.3 h·wk^{-1} 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 ($P_{trend} < 0.0001$) and combined sedentary behavior ($P_{trend} = 0.0002$) but not in watching TV ($P_{trend} = 0.07$). 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 ($P_{trend} = 0.01$) and combined sedentary behavior ($P_{trend} = 0.04$). Participants who reported >10 h·wk^{-1} riding in a car had a 50% greater risk of dying from CVD than the referent group (reporting <4 h·wk^{-1}) after adjusting for multiple variables. After combining the reported hours of sedentary behavior, participants who reported >23 h·wk^{-1} of sedentary behavior had a 37% greater risk of CVD mortality compared with individuals who reported <11 h·wk^{-1}. 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 the CVD mortality, we stratified data by follow-up time (0–10, 11–15, and 15+ yr). The associations between time watching TV and CVD mortality were consistent across the follow-up period. The associations between riding in a 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 the 95% CI by quartiles of time in riding in a car across groups according to age (Fig. 1A), BMI (Fig. 1B), physical activity category (Fig. 1C), and hypertension status (Fig. 1D). HR were significantly associated with the time spent riding in a car within stratum of being younger (<60 yr 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.

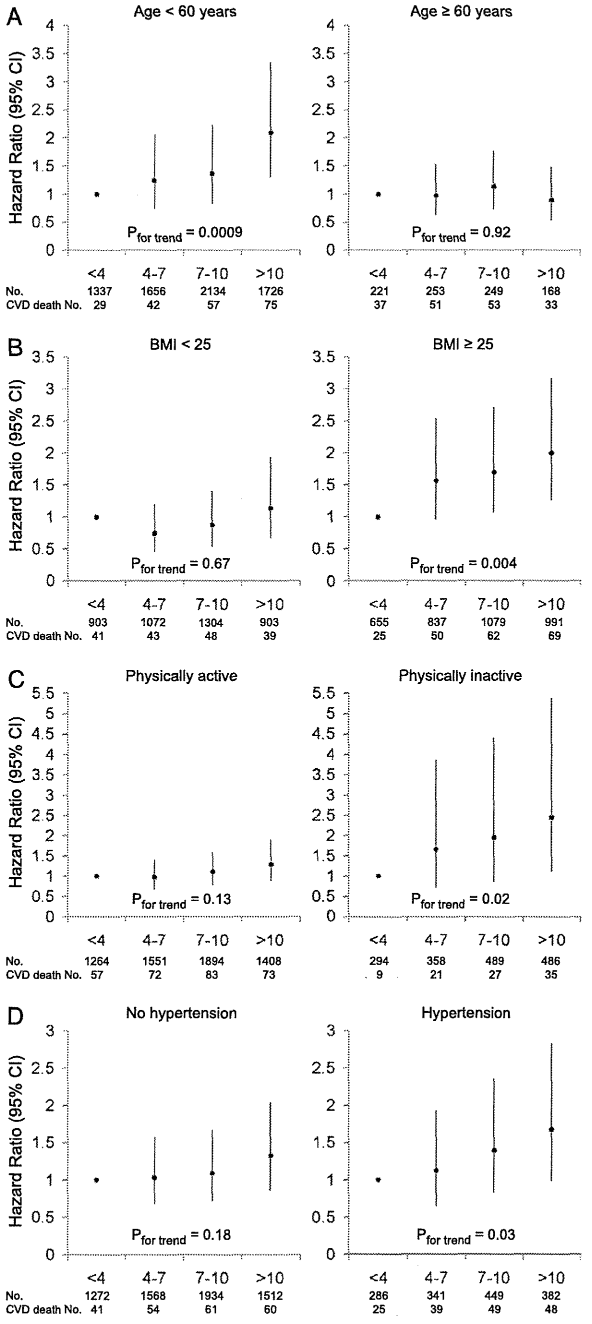

FIGURE 1—Multivariate-adjusted* HR and 95% confidence intervals (CI) by quartiles of time spending in riding in a car across age groups (A), body mass index (BMI) groups (B), physical activity categories (C), and hypertension status (D) in 7744 men. *Adjusted by age, current smoker, alcohol intake (less than one, between one and two, and more than two drinks per day), family history of CVD, diabetes, hypercholesterolemia, and each of other variables in the figures. Likelihood ratio test for interaction, $\chi^2 = 3.21$, $df = 1$, $P = 0.07$, for age–riding in a car; $\chi^2 = 3.67$, $df = 1$, $P = 0.055$, for BMI–riding in a car; $\chi^2 = 2.53$, $df = 1$, $P = 0.11$, for physically inactive–riding in a car; and $\chi^2 = 0.24$, $df = 1$, $P = 0.62$ for hypertension–riding in a car.

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 h·wk^{-1}) and combined sedentary behavior (>23 h·wk^{-1}) remained significantly associated with 48% and 37% increased risk of CVD mortality, respectively, as compared with the referent groups (<4 and <11 h·wk^{-1}). Results further showed that, regardless of time spent in riding in a car or in combined sedentary behavior, being older, having normal weight, being normotensive, and being 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 that 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 Crawford (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 with bus conductors. The present study indicated that riding in a car >10 h·wk^{-1} increased CVD mortality risk by 48%. Further research in diverse groups of men and women is 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 h·d^{-1} 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 watching TV as the second and the 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 (Fig. 1C) 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, are 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 yr) 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 of 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 1 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 7744 men, participants were at significantly greater risk of CVD mortality if they reported riding in a car >10 $h \cdot wk^{-1}$ or participated in >23 $h \cdot wk^{-1}$ 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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対象の内訳		ヒト	動物	地域		研究の種類	
	対象	一般健常者	空白		欧米		縦断研究
	性別	男性	( )		( )		コホート研究
	年齢	20-89(47.1歳)	[redacted]		( )		( )
	対象数	5000～10000			( )		前向きコホート
					( )		( )
調査の方法	質問紙	( )					
アウトカム	予 防	なし	なし	なし	なし	(死亡)	( )
	維持・改善	な し	な し	な し	なし	(	( )

図 表

TABLE 2. HR (95% CI) of CVD mortality according to quartiles of sedentary behaviors.

	Quartiles of Sedentary Behavior				
	1 (lowest)	2	3	4	P_{trend}
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Multivariate HR (95% CI)[a]	1	1.09 (0.78–1.52)	1.23 (0.89–1.70)	1.50 (1.08–2.09)	0.01
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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)	
Multivariate HR (95% CI)[a]	1	1.02 (0.74–1.42)	1.27 (0.90–1.78)	0.96 (0.68–1.36)	0.94
Combined sedentary behavior ($h \cdot wk^{-1}$)					
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)[a]	1	1.09 (0.77–1.54)	1.33 (0.96–1.83)	1.37 (1.01–1.87)	0.04

[a] Adjusted for age, physically inactive, current smoker, alcohol intake (less than one, between one and two, and more than two drinks per day), BMI, family history of CVD, hypertension, diabetes, and hypercholesterolemia.

図表掲載箇所	
概 要 (800字まで)	＜目的＞座位時間≒不活動時間が循環器疾患による死亡とどのように関連するかについて検討すること。＜方法＞コホート名：Aerobic center longitudinal study (ACLS)、対象者数：7744人、追跡期間：21年、因子評価方法詳細：週当たりの自動車運転時間＋TV視聴時間を座位時間と定義。週当たりの座位時間が11時間未満, 11-15時間, 16-23時間, 23時間より大の4分位に分類、因子の単位：時/週。座位時間は身体活動量と強い相反関係にあるので、身体活動量を交絡因子として分析をした。死亡データは、2003年12月31日まで国の死亡登録によって確かめた。コックス回帰分析により、座位時間(テレビを見ている時間、車に乗っている時間とこれらの2つの合計時間)とCVD死亡率の間の関係を定量化した。＜結果＞自動車運動に対する総死亡リスクは、分位1：1、分位2：1.09 (0.78-1.52)、分位3： 1.23 (0.89-1.70)、分位4： 1.50 (1.08-2.09)であった。時間2つの座業時間の合計時間に対する相対死亡リスクは分位1：1、オ分位2：1.09(0.77-1.54)、分位3：1.33(0.96-1.83)、分位4：
結 論 (200字まで)	男性の循環器疾患による死亡リスクは乗車時間とTV視聴時間の合計により算出された座位時間が週当たり24時間以上(1日当たり3. 4時間より長いと有意に高くなる。また、座位時間と独立し、身体活動量が多いと死亡リスクが低い.
エキスパートによるコメント (200字まで)	座位時間と身体活動量の相互作用を検討した意義のある研究である。

担当者 宮地元彦

6. 握力の
参照値算出に用いた文献

Handgrip Strength and Mortality in Older Mexican Americans

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Glenn V. Ostir, PhD,[*†‡] *and James S. Goodwin, MD*[*†‡]

OBJECTIVES: To examine the association between handgrip strength and mortality in older Mexican American men and women.

DESIGN: A 5-year prospective cohort study.

SETTING: Five southwestern states: Texas, New Mexico, Colorado, Arizona, and California.

PARTICIPANTS: A population-based sample of 2,488 noninstitutionalized Mexican-American men and women aged 65 and older.

MEASUREMENTS: Maximal handgrip strength, timed walk, and body mass index were assessed at baseline during 1993/94. Self-reports of functional disability, various medical conditions, and status at follow-up were obtained.

RESULTS: Of the baseline sample with complete data, 507 persons were confirmed deceased 5 years later. Average handgrip strength ± standard deviation was significantly higher in men (28.4 kg ± 9.5) than in women (18.2 kg ± 6.5). Of men who had a handgrip strength less than 22.01 kg and women who had a handgrip strength less than 14 kg, 38.2% and 41.5%, respectively, were dead 5 years later. In men in the lowest handgrip strength quartile, the hazard ratio of death was 2.10 (95% confidence interval (CI) = 1.31–3.38) compared with those in the highest handgrip strength quartile, after controlling for sociodemographic variables, functional disability, timed walk, medical conditions, body mass index, and smoking status at baseline. In women in the lowest handgrip strength quartile, the hazard ratio of death was 1.76 (95% CI = 1.05–2.93) compared with those in the highest handgrip strength quartile. Poorer performance in the timed walk and the presence of diabetes mellitus, hypertension, and cancer were also significant predictors of mortality 5 years later.

CONCLUSION: Handgrip strength is a strong predictor of mortality in older Mexican Americans, after controlling for relevant risk factors. J Am Geriatr Soc 50:1250–1256, 2002.

Key words: grip strength; aging; mortality; survival analysis; Mexican Americans

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Studies predicting mortality in older people aim to identify risk factors enabling early intervention and effective treatment and rehabilitation to help increase active life expectancy and improve quality of life.[1] These factors include age, gender, physical and mental health, self-rated health, and lifestyle behaviors.[1–3]

Decreased muscle strength in old age is related to functional limitations and upper and lower body disability. Factors associated with muscle weakness in upper and lower extremities in older people include decreased physical activity, lower hormone levels, lower body weight, undernutrition, chronic disease, and more medications to treat disease.[4–19] Poor upper body muscle strength as measured by handgrip strength has been associated with disability in older people.[20–23] Poor lower body function, as measured by tests of walking, balance, and chair stands, is associated with poor health status, physiological alterations such as low albumin and hemoglobin levels, poor muscle strength, obesity, physical inactivity, and mortality.[4,18,23–31]

Nevertheless, only a limited number of studies have investigated the association of grip strength with mortality. The grip strength test is commonly used to evaluate the integrated performances of muscles by determining maximal grip force that can be produced in one muscular contraction,[32] and grip strength has frequently been used as a marker for general muscle strength.[10,33]

Laukkanen et al.[1] found a strong association between grip strength and mortality in a cohort of older people in Jyväskylä, Finland. Rantanen et al.[34] reported a gradient of decreasing mortality risk with increasing grip strength in a cohort of men living in Hawaii. Phillips et al.[35] found that reduced grip strength was associated with increased risk of mortality in women with acute illness. Fujita et al.,[36] in health-promotion centers in Japan, found a rela-

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tionship between low grip strength and increased risk of death in men but not in women.

Little is known about muscle strength as a predictor of mortality in older Mexican Americans. The purpose of this study was to examine muscle strength estimated by handgrip strength as a predictor of mortality using a large population-based sample of older Mexican-American men and women over a 5-year period. Because of gender differences in muscle strength, the analysis was conducted separately for men and women.[4,7,9]

METHODS

Sample

Data employed are from the Hispanic Established Population for the Epidemiological Study of the Elderly (EPESE), a longitudinal study of Mexican Americans aged 65 and older, residing in Texas, New Mexico, Colorado, Arizona, and California. The Hispanic EPESE was modeled after previous EPESE studies conducted in New Haven, East Boston, rural Iowa, and North Carolina.[37] Subjects were selected by area probability sampling procedures that involved selection of counties, census tracts, and households within selected census tracts. Door-to-door screening yielded in-home interviews with 3,050 older Mexican Americans during the fall of 1993 and spring of 1994. The response rate was 83%, which was comparable with the other EPESE studies;[37] 2,873 subjects were interviewed in person and 177 (5.8%) by proxy. When weighted for the actual number of older Mexican Americans in the five-state area, the sample represents approximately 500,000 Mexican Americans aged 65 and older.

The present study used baseline data and data obtained at the 5-year follow-up assessment (1998/99). For the analysis, we include persons with complete data on the handgrip strength measure and other relevant variables at baseline. Of the 2,488 eligible subjects at baseline, 507 were confirmed dead 5 years later through Epidemiology Resources Incorporated using the Social Security Administration's Death Master Files and reports from relatives. Of the deceased, 261 (24.7%) were men and 246 (17.2%) were women; 193 (6.3 %) additional subjects were lost to follow-up.

MEASURES

Grip Strength Test

Using a hand-held dynamometer (Jaymar Hydraulic Dynamo-meter, model #5030J1, J.A. Preston Corp., Clifton, NJ) handgrip strength was measured in kg at baseline (1993/94). With subjects in a sitting position, with elbow resting on the table and palm facing up, the dynamometer was placed in their dominant hand. Grip size was adjusted so that they felt comfortable while squeezing the grip. Subjects then were instructed and verbally encouraged to squeeze the handgrip as hard as they could. A trained interviewer administered the test, and two trials were performed, with the higher of the two handgrip scores used for scoring purposes. Scores were divided into approximate quartiles, separately, for men and women. For men, a grip strength of less than 22.00 kg received a score of 1, 22.01 to 30.00 kg a score of 2, 30.01 to 35.00 kg a score of 3, and 35.01 kg or more a score of 4. For women, a grip strength of $<$ 14.00 kg received a score of 1, 14.01 to 18.20 kg a score of 2, 18.21 to 22.50 kg a score of 3, and 22.51 kg or more a score of 4. The hand-held dynamometer has been shown to be a reliable and valid instrument in older persons.[8,13,38,39]

Functional Disability

Functional disability was assessed using seven items from a modified version of the Katz activities of daily living (ADL) scale[40] and 10 items from the instrumental activities of daily living (IADL) scale.[41] ADLs include walking across a small room, bathing, grooming, dressing, eating, transferring from a bed to a chair, and using the toilet. The original version of the Katz ADL scale[42] was modified by removing continence, because incontinence may be present in individuals who otherwise display no disability, and by adding grooming and ability to walk across a small room. Subjects were asked whether they could perform the ADL activity without help, if they needed help, or if they were unable to perform the activity. For the analysis, ADL disability was dichotomized as no help needed versus needing help with or unable to perform one or more of the seven ADL activities. IADLs include use of the telephone, driving a car or being able to travel alone, going shopping for groceries/clothes, preparing meals, doing light housework, taking medicine, handling money, doing heavy work around the house, walking up and down stairs, and walking half a mile. Subjects were asked to indicate whether they could perform the IADL activity alone or needed help performing the activity. For the analysis, IADL disability was dichotomized as no help needed versus needing help to perform one or more of the 10 IADL activities.

Performance-Based Measures of Mobility

In this analysis, we used an 8-foot timed walk as a measure of mobility. This measure has been shown to be the most discriminating lower body measure of future functional ability[31] and was a strong predictor of short-term mortality[29] in the present sample. An 8-foot walk was timed twice to the nearest second with the faster of the two walks used for scoring purposes.[31] Scores were divided into approximate quartiles. A time of 9.0 seconds or longer received a score of 1, 6.0 to 8.0 seconds a score of 2, 4.0 to 5.0 seconds a score of 3, and 3.0 seconds or less a score of 4; higher scores indicate faster walking speed. The 8-foot walk measure has demonstrated a high test-retest reliability.[43–45]

Covariates

Baseline sociodemographic variables include gender, age (65–74, 75–84, $\geq$85), marital status, years of education (0, 1–6, 7–11, $\geq$12), and language of interview (Spanish or English). The presence of various medical conditions was assessed with a series of questions asking subjects whether a doctor had ever told them that they had arthritis, diabetes mellitus, heart attack, hypertension, stroke, cancer, or hip fracture. Body mass index (BMI) was computed by dividing weight in kilograms by height in meters squared. Anthropometric measurements were collected in the home using the methods and instructions employed in other EPESE studies. Height was measured using a tape placed against the wall and weight using a Metro 9800 measuring scale (Metro Corp., Las Cruces, NM). Four BMI categories were created: less than 22 kg/m², 22 kg/m² to less than 26 kg/m², 26 kg/m² to less than 30 kg/m², and 30 kg/m² or more. Persons with BMIs of 30 or more were considered obese.[46] Smoking status was assessed by asking subjects whether they were a never smoker, current smoker, or former smoker.

Analysis

Five-year mortality was examined using Cox proportional hazards survival analysis separately for men and women. Handgrip strength quartiles were used to calculate the hazard ratio (HR) of death, controlling for sociodemographic variables, functional disability, timed walk, medical conditions, BMI, and smoking status at baseline. Three hierarchical models assessed mortality. In Model 1, handgrip strength quartiles were included along with age. In Model 2, functional disability and timed walk were added. In Model 3, the sociodemographic variables, smoking status, medical conditions, and BMI categories were added. We also analyzed handgrip strength as a continuous variable to investigate whether there was a gradient of risk on mortality. All analyses were performed using the SAS System for Windows, Version 8 (SAS Institute, Inc., Cary, NC).

Table 1. Baseline Characteristics of the Sample by Gender

Variable	Total Sample (N = 2,488)	Men (n = 1,055)	Women (n = 1,433)
Age, n (%)			
65–74	1,651 (66.4)	714 (67.7)	937 (65.4)
75–84	696 (28.0)	275 (26.1)	421 (29.4)
≥85	141 (5.6)	66 (6.2)	75 (5.2)
Marital status, n (%)			
Married	1,402 (56.4)	800 (75.8)	602 (42.0)
Unmarried	1,086 (43.6)	255 (24.2)	831 (58.0)
Education, years, n (%)			
0	428 (17.4)	173 (16.6)	255 (18.0)
1–7	1,455 (59.3)	612 (58.7)	843 (59.5)
8–11	328 (13.3)	137 (13.2)	191 (13.5)
≥12	248 (10.0)	120 (11.5)	128 (9.0)
Language of interview, n (%)			
English	556 (22.4)	246 (23.3)	310 (21.6)
Spanish	1,932 (77.6)	809 (76.7)	1,123 (78.4)
Smoking status, n (%)			
Never smoker	1,404 (56.6)	388 (36.9)	1,016 (71.2)
Current smoker	322 (13.0)	200 (19.0)	122 (8.5)
Former smoker	755 (30.4)	465 (44.1)	290 (20.3)
Handgrip strength, mean ± standard deviation		28.4 ± 9.5	18.2 ± 6.5
Functional disability, n (%)			
Any activity of daily living limitation	252 (10.2)	89 (8.5)	163 (11.4)
Any instrumental activity of daily living limitation	1,277 (51.4)	440 (41.8)	837 (58.5)
Short walk score, n (%)			
0 (unable to do)	121 (5.2)	48 (4.9)	73 (5.5)
1	645 (28.0)	251 (25.4)	394 (29.7)
2	617 (26.6)	221 (22.3)	396 (29.8)
3	689 (29.7)	322 (32.5)	367 (27.7)
4	245 (10.5)	148 (14.9)	97 (7.3)
Arthritis, n (%)	985 (39.8)	298 (28.5)	687 (48.2)
Diabetes mellitus, n (%)	664 (26.8)	291 (27.6)	373 (26.1)
Stroke, n (%)	150 (6.0)	75 (7.1)	75 (5.3)
Heart attack, n (%)	261 (10.5)	130 (12.4)	131 (9.2)
Hypertension, n (%)	1,067 (43.0)	358 (34.0)	709 (49.7)
Cancer, n (%)	134 (5.4)	57 (5.4)	77 (5.4)
Hip fracture, n (%)	78 (3.1)	23 (2.2)	55 (3.8)
Body mass index, kg/m², n (%)			
<22	242 (10.0)	104 (10.1)	138 (9.9)
22–<26	667 (27.4)	312 (30.2)	355 (25.4)
26–<30	786 (32.3)	382 (36.9)	404 (28.9)
≥30	736 (30.3)	235 (22.8)	501 (35.8)

RESULTS

Table 1 presents baseline characteristics of the sample by gender. The average age was 72.8, and 57.6% of the sample was female. Over half of the sample was currently married, and 90% had less than a high school education. Arthritis, hypertension, and diabetes mellitus were the most common medical conditions for both men and women. Handgrip strength average was lower in women than men. Women were more ADL and IADL disabled than men and more obese.

Table 2 shows 5-year mortality by handgrip strength quartiles for men and women. Over the 5-year follow-up period, 261 (24.7%) men and 246 (17.2%) women died. Of the 261 men and 246 women, 38.7% and 41.5%, respectively, were in the lowest handgrip strength quartile.

Tables 3 and 4 present the results of Cox proportional hazards analysis of mortality as a function of handgrip strength, adjusting for sociodemographic variables, smoking status, functional disability, performance-based measures of mobility, selected medical conditions, and BMI for men and women. Model 1, in Table 3 (men only), shows the HR of death associated with handgrip strength quartiles controlling for age. There was a significant gradient of risk for death in men in the lowest handgrip strength quartile compared with the highest handgrip strength quartile. The HR was 2.47 (95% confidence interval (CI) = 1.63–3.73) for those in quartile 1 (lowest), 1.71 (95% CI = 1.13–2.60) in quartile 2, and 1.22 (95% CI = 0.77–1.91) in quartile 3 when compared with men in quartile 4 (strongest). In Model 2, functional disability and timed walk were added. The greatest risk of death was found in men in the lowest two quartiles. In Model 3, sociodemographic variables, smoking status, medical conditions, and BMI were added. The greatest risk of death was found in men in the lowest two quartiles. Poorer performance in timed walk and the presence of diabetes mellitus, hypertension, and cancer were also significant predictors of death in men. Handgrip strength was also used as a continuous variable. Each 1-kg increase in handgrip strength was associated with a 3% decreased risk of mortality (HR = 0.97, 95% CI = 0.95–0.98) after adjusting for variables in Model 3.

Table 2. Five-Year Mortality by Handgrip Strength Quartiles for Men and Women (N = 2,488)

Handgrip Strength Quartiles	Total Sample n (%)	Deceased n (%)
Men	1,055 (100)	261 (24.7)
<22.01 kg	261 (24.7)	101 (38.7)
22.01–30.00 kg	295 (28.0)	81 (31.0)
30.01–35.00 kg	248 (23.5)	46 (17.7)
≥35.01 kg	251 (23.8)	33 (12.6)
Women	1,433 (100)	246 (17.2)
<14.00 kg	359 (25.1)	102 (41.5)
14.01–18.20 kg	351 (24.5)	64 (26.0)
18.21–22.50 kg	378 (26.4)	52 (21.1)
≥22.51 kg	345 (24.0)	28 (11.4)

Model 1, in Table 4 (women only), shows the hazard of death associated with handgrip strength quartiles controlling for age in women. There was a significant gradient of risk for death among women in the lower handgrip strength quartile compared with those in the higher handgrip strength quartiles. The HR was 2.89 (95% CI = 1.87–4.49) for those in the quartile 1 (lowest), 1.91 (95% CI = 1.22–3.01) in quartile 2, and 1.53 (95% CI = 0.97–2.44) in quartile 3 when compared with women in the quartile 4 (strongest). In Model 2, functional disability and timed walk were added. The greatest risk of death was found among women in quartile 1 when compared with those in the last three quartiles. In Model 3, sociodemographic variables, smoking status, medical conditions, and BMI were added. The greatest risk of death was found among women in quartile 1 when compared with those in the last three quartiles. Poorer performance in timed walk, diabetes mellitus, hypertension, and cancer were also significant predictors of death among women. Handgrip strength was also used as a continuous variable. Each 1-kg increase in handgrip strength was associated with a 3% decrease risk of mortality (HR = 0.97, 95% CI = 0.94–0.99) after adjusting for variables in Model 3.

DISCUSSION

We found a strong association between handgrip strength and mortality among men and women over a 5-year period in older Mexican Americans. The association remained after controlling for sociodemographic variables, smoking status, functional disability, performance-based measures of mobility, various medical conditions, and BMI. The results are consistent with earlier findings on the association between handgrip strength and risk of mortality.[1,33–35] The choice of handgrip strength as a measure of muscle strength was based on several studies[1,4,6,7,10,11,13,16,17,22] in which handgrip strength was used as an overall measure of muscle strength and because it is reliable, valid, and easy to administer.[8,13,38,39]

Several factors, such as decreasing physical activity, lower levels of hormones such as testosterone or cortisol, lower body weight, presence of chronic disease, and change in aging muscle itself are known to contribute to the loss of grip strength with age.[4,9–19] Diseases common in old age, such as coronary artery disease, chronic obstructive pulmonary disease, malignancy, osteoarthritis of the hand, and falls are associated with loss of strength and disability, an established risk factor for mortality.[2,3,20,28,29] Furthermore, a positive association has been found between grip strength and bone density. For example, Kritz-Silverstein et al.,[15] in a study of older women, found a significant positive association between grip strength and bone density at all sites, after controlling for age, obesity, exercise, cigarette smoking, thiazide use, arthritis, number of years postmenopause, and estrogen use.

Older Mexican Americans have high rates of diabetes mellitus, low rates of physical activity, and high rates of disability.[47] One study found a negative cross-sectional association between handgrip dynamometer and fasting insulin level after adjustment for potential confounders, which suggests that decreased muscle strength may serve as a marker for the risk of increased insulin resistance as indicated by hyperinsulinemia.[14]

Table 3. Hazard Ratio Models Predicting Mortality from Handgrip Strength at 5-Year Follow-Up for Men

Variable	Model 1 n = 1,055*	Model 2 n = 986*	Model 3 n = 959*
	hazard ratio (95% confidence interval)		
Age	1.05 (1.03–1.07)	1.05 (1.03–1.07)	1.03 (1.01–1.06)
Marital status, married†			0.79 (0.58–1.07)
Education, years			
0			1.58 (0.86–2.89)
1–7			1.43 (0.84–2.45)
9–11			1.74 (0.93–3.24)
≥12†			
Smoking status			
Never smoker†			
Current smoker			1.20 (0.79–1.81)
Former smoker			1.19 (0.87–1.63)
Handgrip strength quartiles			
1	2.47 (1.63–3.73)	1.85 (1.17–2.94)	2.10 (1.31–3.38)
2	1.71 (1.13–2.60)	1.58 (1.01–2.45)	1.63 (1.04–2.55)
3	1.22 (0.77–1.91)	1.17 (0.73–1.88)	1.30 (0.80–2.11)
4†			
Any activity of daily living limitation		1.55 (0.95–2.52)	1.39 (0.82–2.35)
Any instrumental activity of daily living limitation		1.23 (0.92–1.65)	1.12 (0.82–1.54)
Short walk score			
0 (unable to do)		2.56 (1.23–5.36)	2.62 (1.22–5.64)
1		2.17 (1.25–3.78)	2.28 (1.29–4.03)
2		1.75 (1.00–3.08)	1.63 (0.92–2.89)
3		1.74 (1.00–3.02)	1.59 (0.91–2.78)
4†			
Arthritis			0.74 (0.51–1.00)
Diabetes mellitus			1.63 (1.22–2.18)
Stroke			0.97 (0.59–1.57)
Heart attack			1.26 (0.86–1.85)
Hypertension			1.42 (1.05–1.91)
Cancer			3.04 (2.02–4.59)
Hip fracture			1.23 (0.56–2.70)
Body mass index (kg/m^2)			
<22			0.95 (0.61–1.46)
22–<26†			
26–<30			0.69 (0.49–0.97)
≥30			0.66 (0.44–0.98)

* Include respondents with values for all independent measures.
† Reference category.

An important contribution of this study was the strong influence of handgrip strength on mortality. This association was as strong as the association of diabetes mellitus, hypertension, and cancer with mortality. In addition to handgrip strength being a predictor of mortality, we found that the timed walk was a strong predictor of mortality over 5 years. Handgrip strength and the timed walk are objective, practical, safe measures that clinicians can use as screening instruments for morbidity and mortality. Decreased grip strength and slower walking speed may be useful indicators of subclinical fragility or disability in older populations.

Our study has some limitations. First is generalizability to other populations. Older Mexican Americans are more disabled than non-Hispanic whites and have differing prevalence rates for some diseases than other ethnic groups.[48] Second, we were limited to self-reports of medical conditions.

In conclusion, we found that handgrip strength was highly predictive of mortality in older Mexican Americans and that this association was independent of relevant risk factors. Consequently, increasing strength by physical activity and exercise programs in this age group may have a favorable effect on functional capacity. It is essential to continue efforts to study muscle strength to provide information for purposes of diagnosis and prognosis and for the planning of prevention, rehabilitation, care, and treatment. Additional research is needed to help us understand

Table 4. Hazard Ratio Models Predicting Mortality from Hand Grip Strength at 5-Year Follow-Up for Women

Variable	Model 1 n = 1433*	Model 2 n = 1321*	Model 3 n = 1290*
	hazard ratio (95% confidence interval)		
Age	1.05 (1.03–1.07)	1.04 (1.02–1.06)	1.04 (1.02–1.07)
Marital status, married†			1.20 (0.88–1.62)
Education, years			
0			1.05 (0.57–1.96)
1–7			1.11 (0.63–1.95)
8–11			1.08 (0.55–2.09)
≥12†			
Smoking status			
Never smoker†			
Current smoker			1.74 (1.08–2.81)
Former smoker			1.21 (0.85–1.72)
Handgrip strength quartiles			
1	2.89 (1.87–4.49)	2.00 (1.22–3.26)	1.76 (1.05–2.93)
2	1.91 (1.22–3.01)	1.45 (0.89–2.37)	1.36 (0.82–2.25)
3	1.53 (0.97–2.44)	1.43 (0.89–2.31)	1.45 (0.89–2.37)
4†			
Any activity of daily living limitation		1.14 (0.73–1.78)	1.09 (0.67–1.78)
Any instrumental activity of daily living limitation		1.44 (1.03–2.00)	1.41 (1.00–1.98)
Short walk score			
0 (unable to do)		4.57 (1.67–12.53)	3.59 (1.27–10.15)
1		2.78 (1.12–6.93)	2.70 (1.08–6.77)
2		2.49 (0.99–6.22)	2.05 (0.81–5.17)
3		1.74 (0.68–4.42)	1.57 (0.61–4.04)
4†			
Arthritis			0.83 (0.62–1.12)
Diabetes mellitus			1.77 (1.31–2.38)
Stroke			1.34 (0.81–2.22)
Heart attack			1.22 (0.80–1.87)
Hypertension			1.42 (1.06–1.91)
Cancer			2.16 (1.33–3.52)
Hip fracture			0.93 (0.47–1.84)
Body mass index (kg/m^2)			
<22			1.44 (0.92–2.24)
22–<26†			
26–<30			0.86 (0.60–1.25)
≥30			0.60 (0.41–0.89)

* Include respondents with values for all independent measures.
† Reference category.

better why poor handgrip strength is associated with death in older Mexican Americans and other populations of older people.

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