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# **Sitting time and mortality in older adults with disability: a national cohort study**

**Running title:** Sit less and disabled elderly

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## ABSTRACT

**Background.** The progressive aging of the population has increased the number of older adults with disabilities. Regular physical activity has shown to improve health among these individuals, but the effects of sedentary behavior are mostly unknown. Thus, this study examined the association between sitting time and mortality in older adults with disability.

**Methods.** Prospective cohort of 2470 people aged  $\geq 60$  years. In 2000-2011 the study participants reported their sitting time and physical activity levels, and were subsequently followed-up through 2011 to ascertain mortality.

**Results.** During an average follow-up of 8.7 years, 982 deaths occurred. Compared with people who spent seated  $<4$  hours/day, the hazard ratio (95% confidence interval) of mortality was 1.27 (1.07–1.51) in those seated during 4-6 hours/day and 1.55 (1.29–1.87) in those seated for  $>6$  hours/day. Each increment of 1 hour/day in sitting time was linked to a 7%-increase in mortality. Compared with active individuals who spent seated  $<4$  hours /day, those who were inactive and spent seated  $>6$  hours/day showed the highest mortality (hazard ratio 1.82; 95% confidence interval 1.37–2.42).

**Conclusions.** Sitting time is associated with higher mortality in older people with disability. Interventions combining the reduction of sedentary behaviour with increased physical activity should be developed and evaluated in this group of population.

**Key words.** Mortality, disability, physical activity, sedentary, sitting time.

## INTRODUCTION

The increase in life expectancy has led to a progressive and rapid aging of the world population (1,2). Since the frequency and degree of disability increases with age, a major public health challenge is to improve or maintain health of older adults with disability through cost-effective strategies (3,4). Regular physical activity has shown to improve health among older adults with disabilities and, specifically, to protect against the processes that trigger and accelerate disability (5-7).

In addition, there is accumulating evidence that sedentary behavior is an important risk factor for adverse health outcomes, regardless of the physical activity performed (8). Sedentary behavior is defined as those activities done mostly in sitting or reclining positions during waking time that do not substantially increase energy expenditure (i.e. between 1 to 1.5 metabolic equivalents) (8). Although the health effects of sedentary behavior are not well known, too much time spent seated has been associated with several disability-related indicators, such as sarcopenia, osteoporosis, cardiovascular diseases, cognitive impairment and alterations in vision (9-14).

To our knowledge, no study has yet examined the effect of sitting time on the health of older people with disabilities. Moreover, the joint health effect of low sitting time and physical activity in this population is also unknown. Therefore, the aim of this study was to examine the association between sitting time and long-term mortality in older adults with disability. In addition, we assessed the combined impact of sitting time and physical activity on mortality.

## **MATERIAL AND METHODS**

### *Study design and participants*

We used data from the UAM-cohort, comprising 4008 individuals representative of the non-institutionalized population aged 60 years and older in Spain (15,16). This cohort was established in 2000/2001 using probabilistic sampling by multistage clusters. The clusters were firstly stratified according to region of residence and size of municipality. Then, census sections and households were chosen randomly within each cluster. Finally, study participants were selected in sex and age (60-69, 70-79,  $y \geq 80$  years) strata. Information at baseline was collected in the participants' home through personal interviews and physical examination by trained and certified personnel. The study response rate was 71%. Thereafter the individuals were followed-up to 2012 to assess incident death. A total of 2741 individuals who at baseline reported having one or more of the disabilities studied in the present work (see next section) were selected for this analysis.

Written informed consent was obtained from study participants and from an attending family member. The study was approved by the Clinical Research Ethics Committee of the *La Paz* University Hospital in Madrid (Spain).

### *Disability*

At baseline, disability was assessed by asking participants about the difficulty experienced or the need of help in performing 14 activities (16), classified into the following five types: agility, mobility, restriction of daily activities, instrumental activities of daily living, and self-care.

Agility disability was ascertained with the question: Do you experience any difficulty in bending or kneeling? Mobility disability was assessed with the following questions: 1) Do you experience any difficulty in picking up or carrying a shopping bag? 2) Do you experience

any difficulty in climbing one flight of stairs? 3) Do you experience any difficulty in walking several city blocks (a few hundred meters)? Restriction of daily activities was obtained by asking participants: During the past 4 weeks, did you have to refrain from doing any of your daily activities, because of your physical health? Instrumental activities of daily living were measured using the Lawton and Brody's test (17); due to cultural reasons, the questions on individuals' ability to prepare meals, do household chores, and the laundry were excluded in men. Finally, self-care disability was assessed with the following question taken from the Katz test (18): Do you experience any difficulty in bathing or dressing yourself without assistance?

The above types of disability were deemed to be present when the response was affirmative for any of the preceding questions, or when Lawton and Brody's test score was  $\leq 4$  among men and  $\leq 7$  among women; these cutoffs correspond to the existence of disability in at least one instrumental activity in each sex.

### *Sitting time*

Sitting time was estimated by leisure time spent sitting down with the following question (19): How much time do you spend sitting down on weekdays? Please, add up the total number of hours for all activities such as eating, listening to the radio, watching television, reading, sewing, driving, etc. The same question was asked for the weekend days. The average hours per day seated on a typical week was calculated as follows:  $[(\text{weekday sitting time} \times 5 + \text{weekend sitting time} \times 2)/7]$ . Participants were classified into tertiles of sitting time with cutoffs at 4 and 6 h/day.

### *Mortality*

The outcome variable was all-cause mortality from the study baseline (2000/2001) to the end of follow-up at December 31, 2011. After authorization from the Ministry of Health, the number and dates of deaths were obtained by a computerized search of the National Death Index. The vital status was successfully ascertained for 99.9% of the cohort.

### *Covariates*

Age, sex, and the highest educational level attained (no formal education, primary, and secondary or higher) were recorded. Participants also reported their smoking and alcohol drinking status. Physical activity was assessed with a single global question that asked participants to rate their behavior as very active, moderately active, less active, or inactive in comparison with their age-peers (19). Those belonging to the highest active category were considered physically active. Also, weight and height were measured using standardized procedures (15), and the body mass index (BMI) was calculated as weight (kg) divided by squared height ( $m^2$ ). Waist circumference was measured with an inelastic belt-type tape at the midpoint between the lowest rib and the iliac crest after breathing out normally (15). Blood pressure was measured six times in the right arm at the level of the heart using standardized methods (20). Readings were taken at 2-min intervals, with the mean of the measurements used in the analyses. Participants were also asked: Has your doctor ever told you whether you have high (blood) cholesterol? If the answer was affirmative, they were considered to have hypercholesterolemia. Cognitive function was assessed with the adapted Mini-Mental State Examination, which is valid for use in the Spanish population (21). Finally, the following diseases diagnosed by a physician and reported by the study participant were also recorded: coronary heart disease, stroke, cancer at any site, diabetes mellitus, and depression.

### *Statistical analysis*

Of the 2741 study participants with at least one disability, 259 were excluded because of missing information on sitting time or the covariates. Also, 12 participants were excluded because of implausible reports of sitting time (0 and >20 h/day). Thus, the final analyses were conducted with 2470 individuals (1541 women). Baseline characteristics of the study participants are presented as mean  $\pm$  SD or percentages.

The association of sitting time (<4, 4-6, >6 h/day) with mortality were summarized with hazard ratios (HR) and their 95% confidence interval (CI) obtained from Cox regression. Three models, with progressive adjustment for potential confounders, were fitted. The first model adjusted for age (years), and sex; the second model further adjusted for educational attainment (no formal education, primary, secondary or higher), body mass index (kg/m<sup>2</sup>), waist circumference (cm), systolic blood pressure (mm Hg), hypercholesterolemia (yes, no), smoking (currently, former, never), alcohol consumption (currently, former, never), Mini-Mental State Examination (score 0-30), coronary heart disease (yes, no), stroke (yes, no), cancer (yes, no), diabetes mellitus (yes, no), and depression (yes, no). A final model further adjusted for physical activity (being or not physically active). The dose-response association was tested with a *P* for trend estimated by modeling sitting time as a continuous variable; also the association of 1 hour/day increase in sitting time with mortality was estimated, including a restricted cubic spline to graphically illustrate the relationship between both variables. We replicated the analyses for individuals with each type of disability (agility, mobility, restriction of daily activities, instrumental activities of daily living, and self-care) and added a fourth model which further adjusted for the other four disabilities separately (yes, no).

To assess whether the study associations were modified by physical activity, we built interaction terms defined as products of categories of sitting time by physical activity; next we used likelihood ratio tests to compare models with and without interaction terms. Lastly, we examined the combined impact of sitting time and physical activity on mortality by



modelling six categories of exposure and taking “sitting time <4 hours/day and being active” as the reference category.

To rule out the effect of subclinical disease on the study results and to reduce the likelihood of reverse causality, we repeated the analyses after excluding participants who died in the first year of follow-up. Also, we tested the assumption of proportionality of hazards both graphically and with interaction terms for sitting time and years of follow-up. No evidence was found of departure from the proportional hazards assumption ( $P>0.2$ ). Finally, since we found no evidence that the association between sitting time and mortality varied with sex or age ( $P$  for interactions  $>0.1$ ), all analyses are presented for the whole sample. All tests were 2-sided and statistical significance was set at  $P<0.05$ . Analyses were performed with STATA® 11.2 for Macintosh.

## RESULTS

The baseline characteristics of the study participants are presented in Table 1. Most individuals had no primary education (58%), and never consumed alcohol (55%) or tobacco (70%). The most frequent disabilities were in agility (81%) and mobility (64%), and the least frequent was in self-care (24%).

During an average follow up of 8.7 years, 982 deaths occurred. Compared with individuals who were seated <4 h/day, the age- and sex-adjusted HRs (95%CI) for all-cause mortality were 1.33 (1.12–1.57) for those seated during 4-6 h/day and 1.63 (1.35–1.97) for those seated >6 h/day (Table 2). With further adjustment for the main cofounders (model 2), the associations were only slightly attenuated (Table 2). Finally, in the model that additionally adjusted for physical activity (model 3), mortality was significantly higher among those who spent seated 4-6 h/day (HR 1.27; 95%CI 1.07–1.51), and >6 h/day (HR 1.55; 95%CI 1.29–1.87) (Table 2).

Figure 1 shows that differences in mortality between individuals who spent in sitting time <4 hours/day and > 6 h/day appeared from the first year of follow-up, while mortality differences between those who spent 4-6 h/day and >6 h/day were observed only after the second or third year. In analyses adjusting for all covariates including physical activity, sitting time showed a progressive dose-response relationship with mortality ( $P$  for linear trend <0.001) (Figure 2); the HR (95% CI) of mortality associated with 1 h/day increase in sitting time was 1.07 (1.05–1.10).

Table 3 presents the associations between sitting time and mortality risk by type of disability. In fully adjusted analyses, including physical activity and the rest of disabilities, a longer time spent seated was associated with higher mortality among participants with each type of disability ( $P$  for linear trend <0.01 in all cases).

We found no evidence that physical activity modified the association between sitting time and mortality ( $P$  for interaction = 0.997, and Figure 3). Also when analyzing the combined effect of sitting time and physical activity on mortality, inactive individuals who spent seated >6 h/day had almost double mortality than those who were active and spent seated <4 h/day (HR 1.82, 95% CI 1.37–2.42, and Figure 3).

We repeated the analysis after excluding 64 deaths that occurred in the first year of follow-up to rule out the influence of preexisting disease. The main results did not substantially change; HRs (95% CI) of mortality for categories of 4-6 h/day and >6 h/day were 1.25 (1.04–1.50) and 1.47 (1.22–1.79) respectively, compared with those who spent <4 h/day in sitting time.

## DISCUSSION

In a national cohort of older adults with disability in Spain, our results showed a clear dose-response relationship between sitting time and mortality, which was independent of physical activity. These results held for each type of disability, including the most severe such as in self-care. Moreover, mortality was lowest among individuals who were active and least sedentary. These results support clinical and public health interventions to promote physical activity and reduce sitting time in this population.

Older people with disability show greater use of healthcare services and higher risk of death than those free of disability (4). In the UAM cohort, and compared to men with no limitation in IADL, a higher percentage of those with limitation in one IADL in 2000-2001 made use of both home (odds ratio [OR] 2.64; 95% CI 1.73–4.03) and non-home health services (OR 2.02; 95% CI 1.04–3.93) in the period 2001–2003 (22). In addition, limitation in one IADL among women was associated with a greater utilization of home services (OR 1.50; 95% CI 1.05–2.14) and visits to hospital specialists (OR 1.61; 95% CI 1.21–2.15) (22). Also in the UAM-cohort, individuals with disability had higher age- and sex-adjusted mortality (HR 1.52; 95% CI 1.28–1.81) than those without disability. Thus, our results are of particular relevance because they identified specific behaviors linked to better vital prognosis in a population at very high risk of adverse health outcomes.

Our results are also important because disabled older adults are very sedentary (23). In the UAM-cohort, participants with disability spent seated 0.86 hours/day more than their non-disabled peers, and the difference in sitting time was even higher (+1.87 h/day) in those with self-care limitations. Thus, replacing sitting time by light physical activity could be a sensible means to improve health in this population (24).

Several mechanisms could explain the association between sedentary behavior and higher mortality independently of physical activity. Too much sitting time could be related to

increased cardiovascular, metabolic, bone, muscle, cognitive, and even ophthalmologic risk (9-14), which are, in turn, associated with disability. For example, a recent systematic review and meta-analysis with 800,000 participants found that sedentary time was positively associated with incidence of diabetes, cardiovascular events, and cardiovascular mortality (9). Also in the National Health and Nutrition Examination Survey (NHANES), objectively-measured sedentary time was associated with higher levels of traditional cardiometabolic risk factors (i.e. obesity, HDL-cholesterol, triglycerides, glucose, blood pressure), inflammatory proteins, as well as lower levels of bone mineral content (10,11). Moreover, Gianoudis et al. (12) have found that accelerometer-measured sedentary time was associated with reduced muscle mass and increased risk of sarcopenia. In addition, in the National Health Interview Survey, prolonged sitting time was associated with prevalent cataracts (13). Lastly, analyses of data from the Age, Gene/Environment Susceptibility-Reykjavik Study have suggested a link between sedentary time and brain atrophy (14).

Increasing and maintaining a physically active lifestyle could be one of the main strategies against age-related disability and its progression. Specifically, several public health organizations recommend that older adults should be as physically active as their clinical conditions allow (5,25). Interestingly, our study shows that mortality was highest among individuals who were inactive and spent too much time seated. Therefore, comprehensive programs to promote recommended physical activity in this population (i.e. aerobic, strength and balance training) could include strategies to reduce sitting time to achieve greater benefits.

In older adults, the reduction of sedentary behavior will require interventions different to those used to increase physical activity (8). Gardiner et al. (26) were one of the first to test the feasibility of reducing sedentary behavior with an intervention based on feedback and on increasing the number of breaks in sitting time for 6 days in subjects aged 60 or older. They obtained encouraging results; the time spent in sedentary behavior decreased by 3%

( $P < 0.001$ ) and the number of breaks in sedentary behavior increased by 4 per day ( $P = 0.003$ ). This study also found that older persons commonly replace sedentary behavior with light-intensity physical activity. These results have been confirmed in other studies (27,28). Given that it is difficult that disabled older adults, who are usually very sedentary, replace sitting time with moderate or vigorous physical activity (24), most interventions should focus on increasing light-intensity physical activity, such as household chores, gardening, walking at slow pace, or even doing in a standing position some habitual sedentary activities (e.g. reading or watching television) (24).

Strengths of this study include a long-term follow-up of a national cohort, standardized data collection by trained personnel, statistical adjustment for many confounders, and sensitivity analyses to minimize reverse causation. However, the study also had some limitations. First, sitting time was ascertained only at baseline; thus, despite the evidence of certain stability over time in older adults, some changes in this behavior may have occurred (29,30). It could have led to underestimating the effect of sitting time on mortality. In addition, sitting time and physical activity were self-reported, so our results should be interpreted with caution due to potential recall and desirability biases. Although similar self-report measures have demonstrated adequate validity and reliability (31), our findings should be confirmed in studies with objective measures (e.g. accelerometers) of sedentary behavior and physical activity (32). Lastly, our study did not include institutionalized individuals, who have more severe disabilities and are more sedentary than community-dwellers of the same age. Thus, future studies should investigate the health effects of sitting time in institutionalized persons.

In conclusion, sitting time was associated with higher long-term mortality in disabled older adults independently of physical activity. Moreover, mortality risk was highest in those who were inactive and most sedentary. Future research should include objective measures of both sedentary behaviors and physical activity to confirm these results and provide more

accurate estimates. Also, interventions combining the reduction of sedentary behavior with increased physical activity should be developed and evaluated with randomized trials in this group of population.

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Table 1. Baseline characteristics of cohort participants (2000/2001)

<i>n</i>	2470
Women, %	62.4
Age, years	72.7±8.0
Educational attainment, %	
No education	58.0
Primary	32.0
Secondary or higher	10.0
Body mass index, kg/m <sup>2</sup>	29.2±4.7
Waist circumference, cm	99.5±12.3
Systolic blood pressure, mm Hg	144.3±19.9
Hypercholesterolemia, %	26.6
Alcohol drinking, %	
Currently	31.9
Former	12.7
Never	55.4
Smoking, %	
Currently	8.6
Former	21.3
Never	70.0
Type of disability, %	
Agility	81.0
Mobility	63.5
Restriction of daily activities	33.5
Instrumental activities of daily living	50.6
Self-care activities (bathing/dressing)	23.9
Mini-Mental State Examination, score 0-30	24.9±4.6
Coronary heart disease, %	7.0
Stroke, %	3.6
Cancer, %	2.3
Diabetes mellitus, %	17.1
Depression, %	12.3
Physically active, %	25.3
Sitting time, hours/day	5.0±2.7

Table 2. Mortality risk according to sitting time in older adults with disability

	Sitting time			<i>P</i> for trend
	< 4 hours/day	4-6 hours/day	> 6 hours/day	
<i>n</i>	879	990	601	
Deaths	258	397	327	
Model 1 HR (95%CI)	1 (Reference)	1.33 (1.12-1.57)	1.63 (1.35-1.97)	<0.001
Model 2 HR (95%CI)	1 (Reference)	1.28 (1.08-1.53)	1.59 (1.33-1.91)	<0.001
Model 3 HR (95%CI)	1 (Reference)	1.27 (1.07-1.51)	1.55 (1.29-1.87)	<0.001

HR: Hazard ratio; IC: Confidence interval.

Model 1: adjusted for age and sex.

Model 2: adjusted as in model 1 and for educational attainment, body mass index, waist circumference, systolic blood pressure, hypercholesterolemia, smoking, alcohol consumption, Mini-Mental State Examination, coronary heart disease, stroke, cancer, diabetes mellitus, and depression.

Model 3: adjusted as in model 2 and for physical activity

Table 3. Mortality risk according to sitting time in older adults with disability, by type of disability ( $n=2470$ )

	Sitting time			<i>P</i> <sub>for trend</sub>
	< 4 hours/day	4-6 hours/day	> 6 hours/day	
Agility				
<i>n</i>	680	814	506	
Deaths	207	323	271	
Model 1 HR (95%CI)	1 (Reference)	1.31 (1.08-1.58)	1.67 (1.28-2.03)	<0.001
Model 2 HR (95%CI)	1 (Reference)	1.25 (1.03-1.52)	1.59 (1.30-1.93)	<0.001
Model 3 HR (95%CI)	1 (Reference)	1.24 (1.03-1.51)	1.55 (1.27-1.90)	<0.001
Model 4 HR (95%CI)	1 (Reference)	1.28 (1.05-1.55)	1.38 (1.12-1.69)	0.002
Mobility				
<i>n</i>	524	579	465	
Deaths	165	258	267	
Model 1 HR (95%CI)	1 (Reference)	1.37 (1.12-1.68)	1.69 (1.38-2.08)	<0.001
Model 2 HR (95%CI)	1 (Reference)	1.33 (1.08-1.64)	1.64 (1.33-2.02)	<0.001
Model 3 HR (95%CI)	1 (Reference)	1.33 (1.08-1.64)	1.60 (1.29-1.97)	<0.001
Model 4 HR (95%CI)	1 (Reference)	1.34 (1.08-1.66)	1.48 (1.19-1.84)	<0.001
Restriction of daily activities				
<i>n</i>	262	305	260	
Deaths	90	148	153	
Model 1 HR (95%CI)	1 (Reference)	1.44 (1.09-1.92)	1.74 (1.32-2.31)	<0.001
Model 2 HR (95%CI)	1 (Reference)	1.37 (1.03-1.83)	1.75 (1.32-2.32)	<0.001
Model 3 HR (95%CI)	1 (Reference)	1.36 (1.02-1.81)	1.63 (1.23-2.17)	<0.001
Model 4 HR (95%CI)	1 (Reference)	1.42 (1.06-1.92)	1.49 (1.11-1.89)	0.007
Instrumental activities of daily living				
<i>n</i>	374	458	417	
Deaths	147	231	276	
Model 1 HR (95%CI)	1 (Reference)	1.28 (1.03-1.59)	1.68 (1.34-2.11)	<0.001
Model 2 HR (95%CI)	1 (Reference)	1.24 (1.00-1.55)	1.65 (1.33-2.06)	<0.001
Model 3 HR (95%CI)	1 (Reference)	1.24 (1.00-1.54)	1.61 (1.28-2.02)	<0.001
Model 4 HR (95%CI)	1 (Reference)	1.27 (1.01-1.58)	1.51 (1.20-1.91)	<0.001
Self-care (bathing/dressing)				
<i>n</i>	146	183	261	
Deaths	66	102	178	
Model 1 HR (95%CI)	1 (Reference)	1.45 (1.05-2.01)	1.64 (1.22-2.20)	<0.001
Model 2 HR (95%CI)	1 (Reference)	1.48 (1.06-2.05)	1.66 (1.22-2.25)	<0.001
Model 3 HR (95%CI)	1 (Reference)	1.49 (1.07-2.08)	1.59 (1.17-2.18)	0.001
Model 4 HR (95%CI)	1 (Reference)	1.50 (1.07-2.14)	1.57 (1.14-2.15)	0.003

Hazard ratio; IC: Confidence interval.

Model 1: adjusted as in table 2.

Model 2: adjusted as in table 2.

Model 3: adjusted as in table 2.

Model 4: adjusted as in model 3 in table 2 and for having or not any of the other four types of disability separately.

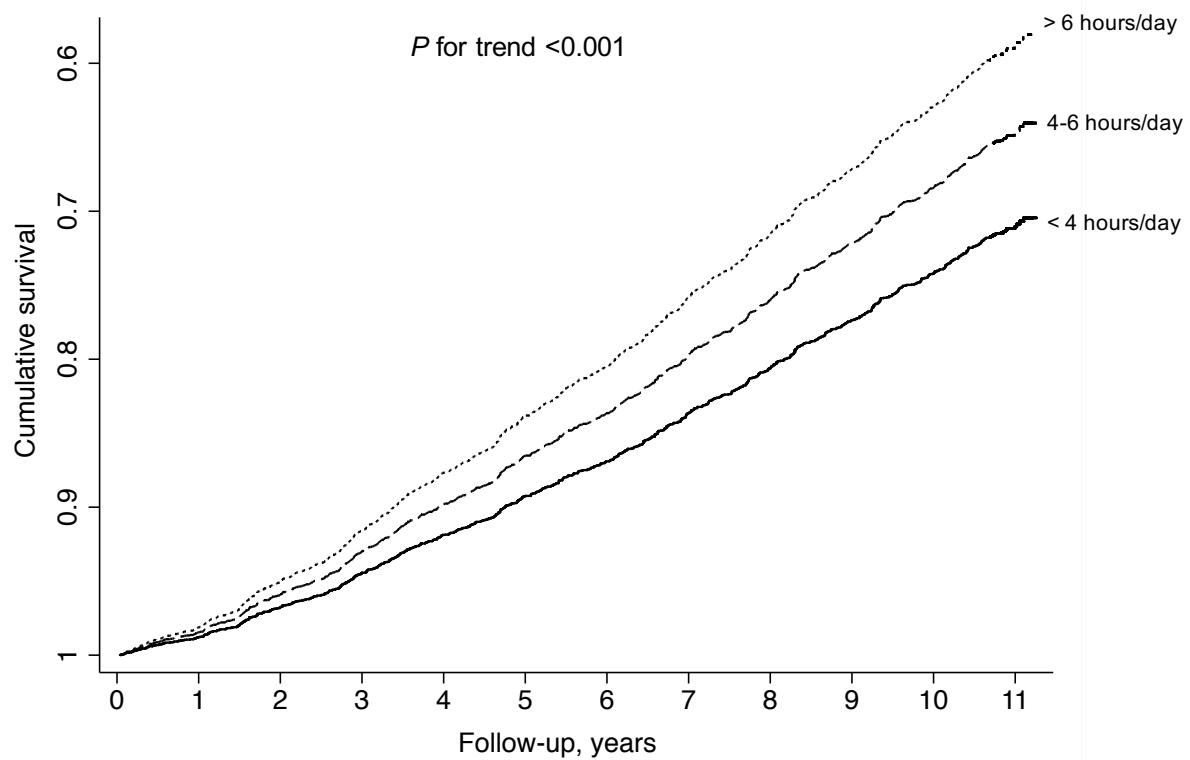


Figure 1. Cumulative survival according to sitting time in older adults with disability ( $n=2470$ ). Analyses were adjusted for age, sex, educational attainment, body mass index, waist circumference, systolic blood pressure, hypercholesterolemia, smoking, alcohol consumption, Mini-Mental State Examination, coronary heart disease, stroke, cancer, diabetes mellitus, depression, and physical activity.

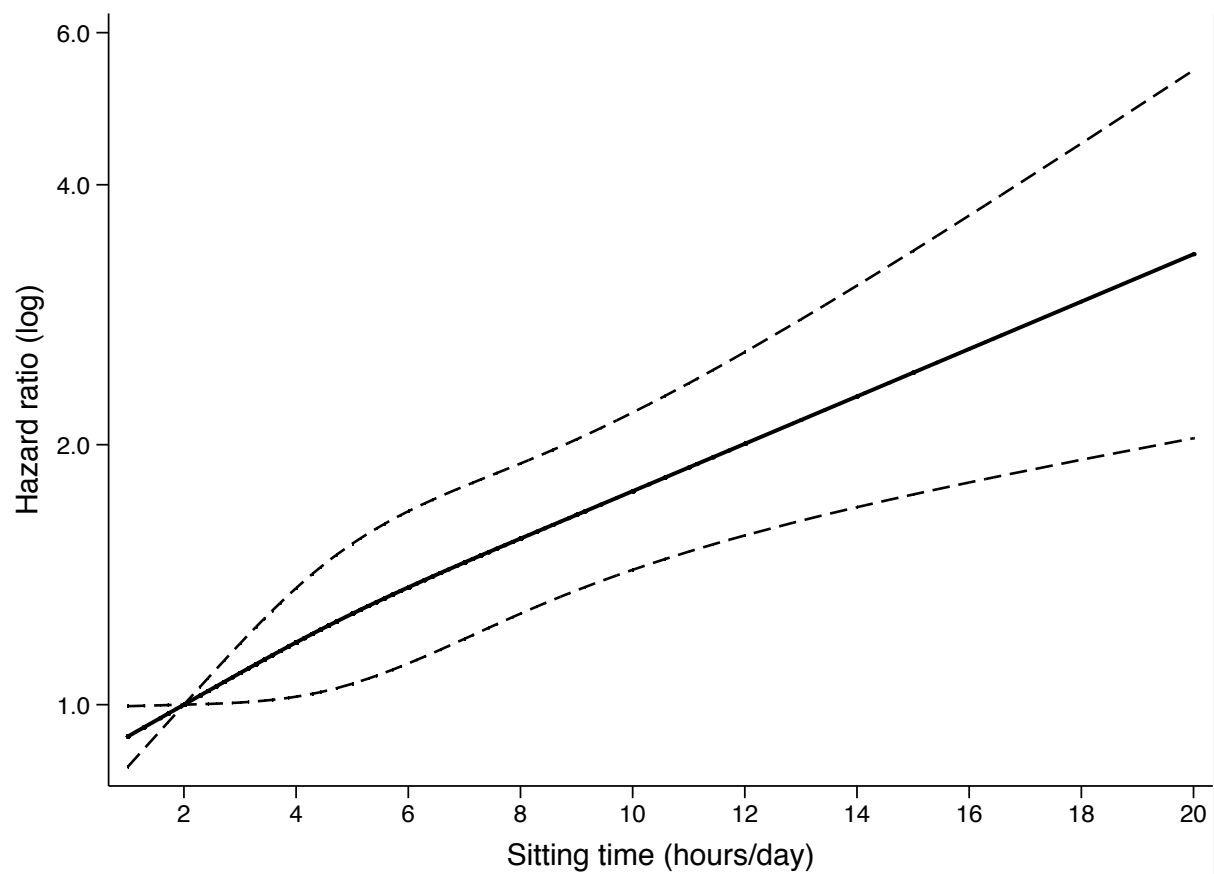


Figure 2. Hazard ratio (solid line) and 95% confidence interval (dashed lines) for mortality according to sitting time in older adults with disability ( $n=2470$ ). Analyses were adjusted for age, sex, educational attainment, body mass index, waist circumference, systolic blood pressure, hypercholesterolemia, smoking, alcohol consumption, Mini-Mental State Examination, coronary heart disease, stroke, cancer, diabetes mellitus, depression, and physical activity.



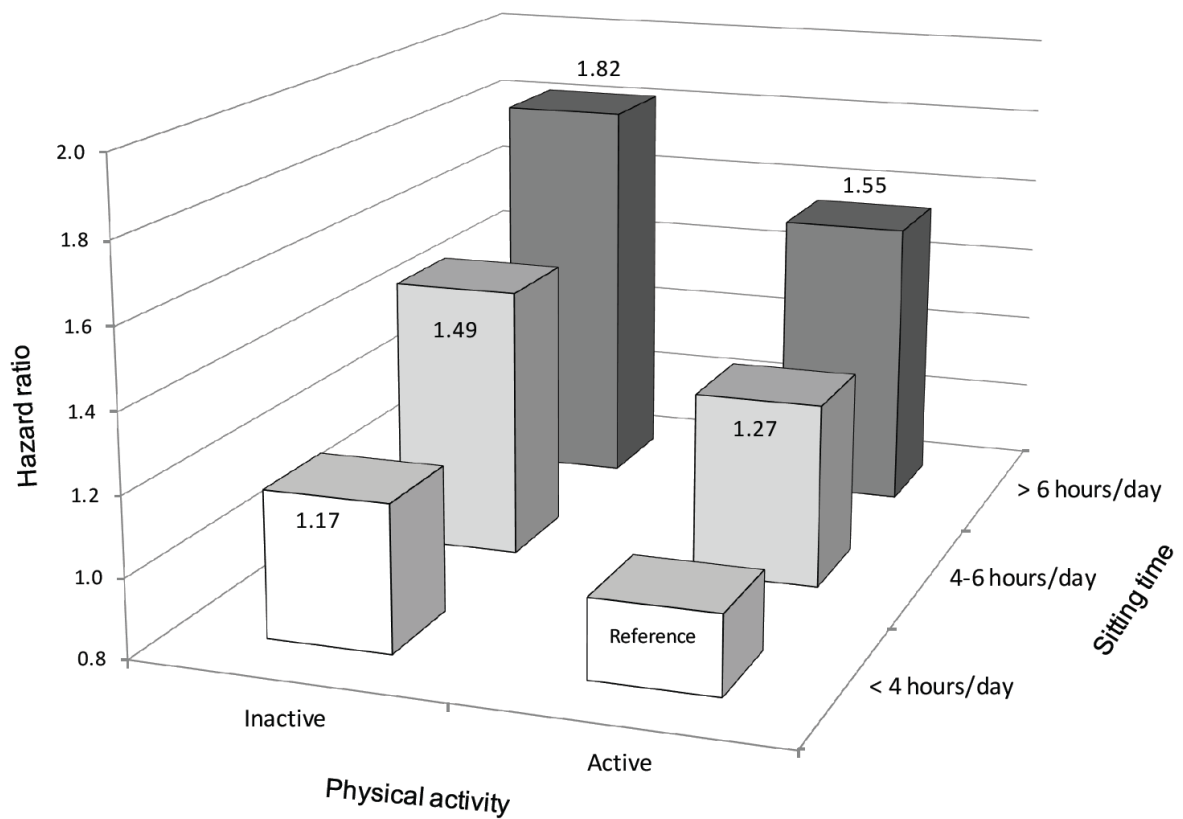


Figure 3. Mortality risk across categories of sitting time and physical activity in older adults with disability ( $n=2470$ ). Analyses were adjusted for age, sex, educational attainment, body mass index, waist circumference, systolic blood pressure, hypercholesterolemia, smoking, alcohol consumption, Mini-Mental State Examination, coronary heart disease, stroke, cancer, diabetes mellitus, and depression.