Association of night-time sleep duration and daytime napping with all-cause and cause-specific mortality in older British men: *Findings from the British Regional Heart Study*

Short title: **Association of sleep patterns with mortality in elderly**

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Author contributorship:

TC reviewed the literature on the topic, had full access to the data in the study, performed the analyses, interpreted the findings, wrote the manuscript and revised and finalised the paper. LL and OP supported the data analysis, interpreted the findings, commented the manuscript. GW conceptualised the study, had full access to the data in the study, supervised the study, interpreted the findings, commented and revised the manuscript.

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SUMMARY

Short and long night-time sleep and daytime napping in young and middle-aged populations were associated with increased mortality, but it is unclear in very older people. The aim of this prospective study was to assess the associations in people aged >70 years. We examined the British Regional Heart Study, which included 1722 men aged 71-92 years and had night-time sleep duration and daytime napping measured at baseline and were followed up for nine years. There were 597 deaths. Compared to night-time sleep at 7-<8 hours, age-adjusted hazard ratio of all-cause mortality in participants sleeping <6 hours was 1.04 (95%CI 0.80-1.35), 1.07 (0.85-1.34) in 6-<7 hours, 1.04 (0.83-1.30) in 8-<9 hour and 0.93 (0.65-1.33) in ≥9 hours. Further adjustments for other co-variables still showed no association, and neither the association with cardiovascular mortality nor non-cardiovascular mortality. Daytime napping, however, was associated with mortality. After adjustment for age, smoking, physical activity, obesity, cardiovascular diseases, diabetes, frailty, general health, anti-hypertensive medication and C-reactive protein level, hazard ratio of all-cause mortality in participants with daytime napping >1 hour versus no napping was 1.62 (1.18-2.22) and hazard ratio of non-cardiovascular mortality was 1.77 (1.22-2.57). The fully adjusted hazard ratio of cardiovascular mortality was not significantly increased (1.26, 0.69-2.28), although age-adjusted hazard ratio was significant (1.94, 1.20-3.16). In the elderly men, daytime napping was independently associated with increased all-cause and non-cardiovascular mortality, while its association with cardiovascular mortality could be explained by cardiovascular risk factors and co-morbidities. Night-time sleep duration was not associated with mortality risk.

Key words: Sleep patterns, night-time sleep, daytime napping, all-cause mortality, cardiovascular mortality, older men

INTRODUCTION

Maintaining a healthy sleep pattern is important for person's physical and mental health, quality of life and longevity. However, it has become a challenge for some people, particularly in older people. While young people need to sleep more hours during night-time (e.g., 9-12 hours in children aged 6-12 years), older people sleep less. The NHS guidelines has recommended for older people (aged ≥60 years) to have 7-8 hours of sleep[1]. However, as people get older their sleep habits and structure change with increased difficulties in initiating and maintaining sleep. As a result, suboptimal sleep quality and sleep disturbances are common in older population[2].

Previous studies of young and middle-aged populations[3,4] showed that both short and long night-time sleep duration increased mortality. However, these associations are not consistent in older people[5-10]. Some studies showed that short sleep duration was associated with increased risk of mortality[11-14], but other studies did not[15-17]. Meanwhile, some studies showed that long sleep duration increased mortality[13,18-20], but others did not[10,15,16]. The association of night-time sleep duration with mortality in older people remains unclear. The differences in the association of night-time sleep duration with mortality may be due to confounders adjusted and vary with age[21]. In a cohort study of 39,191 participants aged ≥18 years from the Swedish Cancer Society, Akerstedt et al[21] found that among people aged <65 years, all-cause mortality increased with short sleep duration at ≤5 hours (hazard ratio (HR) 1.37, 1.09–1.71) and also with long sleep duration at ≥8 hours (1.27, 1.08–1.48) versus those at 7-8 hours. However, among people aged ≥65 years, no such significant associations were observed; the corresponding HRs were 1.05 (0.90-1.22) and 1.01 (0.90-1.14). More cohort studies are required to examine the association of short and long sleep duration with increased mortality in older people. Alongside with increased life expectancy over the past decades, particularly in high income countries (e.g., 80.9 years in the UK 2020[22]), it is important to

identify the impacts of short and long night-time sleep duration on mortality in older people, particularly in very older people.

Afternoon naps are quite common in older people due to a variety of reasons such as chronic conditions, lifestyle changes, cultural beliefs, and age[23,24]. It is estimated that 20 to 60% of older people have a nap during the day globally[25]. A meta-analysis[26] including nine published studies found that daytime napping was associated with increased risks of all-cause mortality (hazard ratio 1.23, 95%CI 1.13–1.35), but the heterogeneity in the findings of the association between daytime napping and mortality was large (I2=58.1%). Few studies have investigated the association between daytime napping and mortality in very older population[26]. All these have urged more studies to determine whether and how long the daytime napping at older age was associated with mortality. In this paper we examined the data of the British Regional Heart Study (BRHS) to assess the associations of night-time sleep duration and daytime napping in older people aged >70 years with all-cause mortality, cardiovascular mortality, and non-cardiovascular mortality, and to investigate factors influencing the associations.

METHODS

Data were drawn from the British Regional Heart Study (BRHS) 30-year re-examination in 2010-12. The methods of the BRHS 30-year re-examination have been fully described in previous papers[27-30]. In brief, the British Regional Heart Study (BRHS) is an ongoing prospective cohort study. It recruited a representative sample of 7735 men aged 40-59 years for a baseline examination in 1978-80. The men were followed up between 1980-2010 with a series of postal questionnaires (every 2-10 years), and a Q20 re-examination in year 1998-2000. In 2010-12, the BRHS 30-year re-examination survey sent surviving cohort members a postal questionnaire, which included sleep patterns questionnaire for data collection. 1,722 men aged 71-92 years returned their completed questionnaires for analysis. We took them as this cohort study baseline and followed them up for mortality. Ethical approval for the BRHS cohort study was obtained from the National Research Ethics Service Committee London (MREC 02/2/91 ID191747)**.**

Baseline data collection in the cohort

Sleep patterns from the questionnaire

Participants were asked to self-report their night-time sleep duration and daytime napping. The night-time sleep duration was based on the response to "*On average, how many hours do you sleep each night"*. It was categorised into five groups; <6, 6-6.99, 7-7.99, 8-8.99, and ≥9 hours. The daytime napping was based on the response to *"how much sleep (if any), do you have during the daytime?".* Participants were categorised into four groups[28] ; 0, <1, 1, and >1 hours.

Covariates

Details of measurements and classification methods for blood pressure, social class, smoking status, alcohol intake and physical activity and frailty have been described[31]. Information on general health status, frailty, disability, and use of blood pressure (BP) lowing medication was obtained from Q30 questionnaire. Presence of comorbidities was based on the participant's

self-report of a doctor's diagnosis (CVD, diabetes, chronic kidney disease (CKD), and arthritis). Physical examination included systolic (SBP) and diastolic blood pressure (DBP), lung function (FEV_1), weight and height from which body mass index (BMI) was calculated. The BMI was grouped based on the WHO classification[32]. Obesity was defined as BMI $\geq$30kg/m^2. Fasting blood samples were taken and blood measurements included blood cholesterol (High-Density Lipoprotein (HDL), glucose, and inflammatory marker [C-reactive Protein (CRP)] and were collected at the re-examination visit. CRP was assayed by ultra-sensitive nephelometry (Dade Behring, Milton Keynes, UK).

Cohort follow-up

All cause, cardiovascular, and non-cardiovascular mortality during the follow-up

Information on mortality of the BRHS cohort was collected through the Office for National Statistics (ONS). The ONS record information included the date of death and the causes of death. The cause of death was coded using International Classification of Diseases, ninth revision (ICD-9)[33]. In this study, all-cause mortality was based on follow-up of the men from the 30-year re-examination in 2010-2012 at baseline to 31st August 2019, which the date of death were censored. The outcomes of interest in this study were all-cause mortality, cardiovascular mortality, and non-cardiovascular mortality.

Statistical analysis

The characteristics of the participants were described and compared across five groups of night-time sleep duration and among four groups of daytime napping duration. The data of continuous variables were displayed as mean and standard deviation and of categorical variables as number and percentage. Differences in continuous covariables among groups were tested by the analysis of variance (one-way ANOVA), and in the categorical variables by the Pearson's χ^2 test.

The Cox regression models were employed to assess the association between sleep pattern and mortality. The covariates, which were put in the Cox regression models for adjustment, were chosen based on evidence from literature or a significant association with the night-time sleep duration/daytime napping through ANOVA or χ^2 test. Statistical models were constructed with progressive adjustment of the covariates: model 1 - unadjusted analysis; model 2 - adjusted for age; model 3 - adjusted for variables in model 2 plus smoking, physical activity, BMI; model 4 - adjusted for variables in model 3 plus CVD, diabetes, frailty, general health, BP medication; and model 5 - adjusted for variables in model 4 plus CRP. These could help identify which factors influenced the association between sleep patterns and mortality. Missing data for covariates were generally low in this BRHS data. A sensitivity analysis was repeated in participants who had complete data on all covariates, i.e., a complete case analysis in the study population. Analyses were implemented in Stata version 17 (StataCorp. 2021. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC).

RESULTS

Of 1722 participants, the average age was 78.55 (SD 4.66) years, and 45.2% were manual workers, 19.9% were obese with BMI of ≥30kg/m^2, and 31.5% had prevalent CVD. Over the 9 years follow-up, there were 597 deaths from all causes (178 CVD deaths, 414 non-CVD death and five from unknown causes of death).

Night-time sleep duration

Characteristics

Thirty-eight men did not have data on night-time sleep duration and thus the data of 1684 participants were analysed. Of 1684 older men, 257 (15.3%) had a night-time sleep duration of <6 hours, 430 (25.5%) had 6-6.99 hours, 434 (25.8%) had 7.00-7.99 hours, 449 (26.7%) had 8.00-8.99 hours and 114 (6.8%) had ≥9 hours. The characteristics of the men by categories of night-time sleeping are presented in Table 1. Men with short (<6 hours) and long (≥9 hours) sleep had more adverse characteristics. They were more likely to be manual workers, physically inactive, frail disabled and report poor/fair general health. They had a higher prevalence of cardiovascular diseases (CVD), use of antihypertensive medication and increased blood glucose, compared to those with 6-8.99 hours' sleep. Long sleep but not short sleep was associated with higher levels of CRP and systolic blood pressure. Those who reported short sleep had the highest prevalence of arthritis. Other factors listed in Table 1 were not significantly different among the night-time sleep groups. The details of different characteristics across the groups of night-time sleep duration can be seen in Table 1.

Night-time sleep duration associated with all-cause, cardiovascular, and non-cardiovascular mortality

Among 1684 men, there were 582 (34.6%) deaths over the 9-year follow-up, with 11,847 person-years at risk (PYAR) in total. Of these 582 deaths, 173 were cardiovascular deaths, 405

were non-cardiovascular deaths, and four were from unknown causes of death. Table 2 shows the number, rate, and hazard ratio of all-cause, cardiovascular, and non-cardiovascular mortality among men with different hours of night-time sleep duration. The rates of of all-cause mortality was the lowest in men with night-time sleep at 7-7.99 hours (4.63/1000 person years) and increased in those with short sleep at 6 <hours (5.3%) and at 6-6.99 hours (4.90%), and with long sleep at 8-8.99 hours (5.00%) and >9 hours (4.90%). However, increased risks of mortality among the short and long sleep groups compared to those sleeping 7-7.99 hours were not statistically significant (Table 2, unadjusted HRs). Adjustment for age, attenuated the risk further. (Table 2, age-adjusted HRs). Further adjustment analyses including social class, lifestyles, general health, CVD and risk factors, comorbidities and use of antihypertensive medication, made little difference to the findings of the associations of short and long sleep hours with all-cause mortality (data not shown). Separate data analysis for CVD mortality and non-CVD mortality showed similar findings to those in all-cause mortality, i.e., they were not significantly related to short or long night-time sleep durations after accounting for age (Table 2) or other factors from Table 2 (data not shown).

Daytime napping

Characteristics

Two hundreds and fifty-four men did not have data on daytime napping and thus the data of 1468 participants were analysed. Of them, 571 (38.9%) reported no daytime napping, 337 (23.0%) reported less than 1 hour daytime napping, 400 (27.3%) reported 1 hour of daytime napping, and 160 (10.90%) reported >1 hour of daytime napping. Men with >1 hour daytime napping had more adverse characteristics than other groups. They were more likely to be older, ex-smokers, physically inactive, have poor general health, frail, disabled, obese ($\geq$30 kg/m^2), have a higher glucose level, CRP count and prevalence of comorbidities, and take antihypertensive medication. Other factors listed in Table 3 were not significantly different

among the daytime napping groups. The details of different characteristics across the groups of daytime napping groups can be seen in Table 3.

Daytime napping associated with all-cause, cardiovascular, and non-cardiovascular mortality

Of 1468 men, 516 (35.1%) died over the 9-year follow-up, of which, 155 were cardiovascular deaths, 357 were non-cardiovascular deaths, and four were from unknown causes of death. Table 4 shows the number, rate, and hazard ratio of all-cause mortality among men with different hours of daytime napping. All-cause mortality rates/1000 person years significantly increased with daytime napping; 3.82% in men having no daytime napping, 4.23% in daytime napping at <1 hour, 6.06% at 1 hour, and 9.27% in those at >1 hour daytime napping. Compared to no daytime napping, age-adjusted HRs of all-cause mortality in men with daytime napping at <1 hour, at 1 hour and at >1 hour daytime napping were 1.03 (0.80-1.32), 1.45 (1.16-1.80) and 2.17 (1.68-2.82) respectively. These HRs were attenuated with further confounding adjustments including lifestyle factors (smoking, physical activity, BMI), comorbidities (CVD, diabetes, frailty, general health, antihypertensive medication and inflammation (CRP), but increased HR in the daytime napping > 1 hours remained significant (1.62, 1.18-2.22) (Table 4).

Separate data analysis for cardiovascular mortality and non-cardiovascular mortality showed similar results in those in all-cause mortality (Table 4), except for increased HR of cardiovascular mortality in men with >1 hour daytime napping being not statistically significant. In the analysis for cardiovascular mortality, age-adjusted HR was significantly increased with >1 hour daytime napping (1.94, 1.20-3.16), but after adjustment for smoking, physical activity and BMI, the association of daytime napping >1 hr with cardiovascular mortality reduced to be not significant (1.52,0.89-2.59), suggesting the association could be explained by these factors. In the analysis for non-cardiovascular mortality, adjustment for smoking, physical activity, and BMI did not substantially change the association; the adjusted

HR in daytime napping >1 hour was 1.96 (1.41-2.74). Further adjustment for comorbidities and CRP, the increased HR remained significant [HR (95%CI) 1.77 (1.22,2.57)] (Table 4).

The sensitivity analysis including all completed data from those adjusted covariables found no significant association of night-time sleep duration with mortality (data not shown). Also, the sensitivity analysis for the association between daytime napping and mortality (Appendix Table 1) showed similar findings in the main analysis in Table 4; for example, age-adjusted HR (95%CI) of all-cause mortality in men with daytime napping >1 hour was 2.17 (1.68-2.82) (versus 2.17, 1.61-2.93 in the main data analysis), of cardiovascular mortality 1.93 (1.10-3.38) (versus 1.94, 1.10-3.38 in the main data analysis), and of Non-cardiovascular mortality 2.27 (1.59-3.24) (versus 2.28, 1.67-3.10 in the main data analysis) respectively.

DISCUSSION

This cohort study of older men aged 71-92 years examined the associations of sleep patterns with all-cause mortality, CVD mortality and non-CVD mortality. There were no significant associations of short and long night-time sleep duration with mortality. However, the daytime napping was significantly associated with mortality risk; participants with daytime napping >1 hour had a 62% increase in all-cause mortality and a 77% increase in non-cardiovascular mortality, and the associations were independent of other factors, including lifestyles, cardiovascular risk factors and co-morbidities. Although its association with increased cardiovascular mortality was significant in age-adjusted analysis, the association was reduced to be not significant after adjustment for smoking, physical activity, and obesity.

Night-time sleep duration and mortality

The current study did not show that short or long duration of sleep was associated with increased mortality, which is different from the findings in most previous studies of older people[5,6,34,35]. The reasons for it could be the small cohort of the BRHS men in the analysis and the age of participants were very old, with a range of 71-92 years and mean of 78.6, which is close to the UK male life expectance of 79.0[22]. A meta-analysis study by He et al[6] found that in those aged ≥65 years, the association of sleep duration with mortality was weakened and the association of short sleep with all-cause mortality was not significant. Other studies also showed no or weak association of sleep duration measured in older age with mortality[21,7,8,13,36,37]. There are a number of explanations for no association between sleep duration and mortality in very older people. First, older people may represent a surviving population that is more resilient to negative health outcomes and have adequate support. Second, the long-standing effects of retirement may impact the precision and accuracy of any sleep duration estimates, therefore weakening the association between sleep duration and mortality. Third, a range of chronic diseases, which increase with aging and cause death, may

dilute the association between sleep duration and mortality since comorbidities have been demonstrated to influence the association between sleep duration and mortality[9,10]. Grandner et al [38] in their systematic review and meta-analysis identified that short sleep was linked with many causes of death, which were due to CVD, obesity, obstructive sleep apnea, diabetes, stress, and immune response, suggesting that these comorbidities may explain the association between short sleep and mortality. Thus, those comorbidities and other risk factors in older people with short or long night-time sleep should be paid more attention to for reducing mortality.

Daytime napping and mortality

In contrast, our study found that daytime napping significantly increased the risk of all-cause mortality and non-cardiovascular mortality, which are consistent with those in other older population studies[39 40 26 41 42]. The association between daytime napping with all-cause and non-cardiovascular mortality in our study may be due to the following factors. In the UK, daytime napping is not a regular part of a daily routine, it is possible that napping could be a sign of subclinical diseases, undiagnosed health problems and an indicator of future health issues, particularly in very older people. Our study (Table 3) showed those with daytime napping had increased CRP level - inflammation index, as other studies did [39]. High level of CRP could link napping with increased all-cause mortality[43]. However, the increased risk of all cause mortality and non-CVD mortality associated with >1 hour day time napping remained after further adjustment for CRP. In this study no association of daytime napping with increased cardiovascular mortality was found after adjustment for smoking, physical inactivity and obesity. Zhong et al [26] pooled the data from six published studies to examine daytime napping associated with cardiovascular mortality and found no significant association either (HR 1.20, 95% CI 0.96-1.50), which was similar to our finding (1.26, 0.69-2.28). We considered that those cardiovascular risk factors and other unknown factors could mediate the association

between daytime napping and cardiovascular morality. Further research is needed to examine how those mediating factors influencing the association in very older people.

Strengths and limitations

To our best knowledge, this study is the first to report the association between daytime napping and increased mortality in very older men. The BRHS is a socioeconomically and geographically representative sample of men across Britain, and its follow-up rate is exceptionally high. Our study included a wide range of rich and in-depth measurements of confounders, which allows for a detailed analysis of factors influencing the association between sleep patterns and mortality. The study has limitations. First, there is a presence of survivorship bias as those who were less healthy were less likely to attend the 30-year re-examination. Therefore, this may underestimate the mortality risk, which could affect the findings of night-time sleep duration with mortality towards a null association. Second, our study included older men only, and its findings could not be applied to older women. Studies of very older women are required to investigate the impact of sleep patterns on mortality. Third, there was lack of measurements of depression and dementia covariables. These co-morbidities could influence on identifying the association between daytime nappy and increased mortality [41,44 45]. However, we adjusted for other important factors, including smoking, CVD, diabetes, and frailty, which were associated with depression and dementia. Thus, the residual effect from these co-morbidities in the analysis would be minimised.

In summary, no significant associations were observed between short/long night-time sleep duration with all-cause, CVD, and non-CVD mortality in British older men. However, daytime napping was significantly associated with increased all-cause and non-CVD mortality which was not explained by lifestyle risk factors, prevalent CVD, diabetes, frailty, reporting of poor health or inflammation . The findings of the study have a major implication on health care in very older people. Individualised health care initiatives are encouraged to support elderly

people who have sleep issues in the community. The association of daytime napping with increased CVD mortality however was explained by potential confounders including smoking, physical inactivity and obesity, The moderating role of comorbidities in the associations warrants further research. The exact mechanisms of the association between daytime napping and the risks of all-cause mortality and non-cardiovascular mortality remain to be further explored.

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Table 1. Distribution of socio-demographic and characteristics among older men with different hours of night-time sleep duration

Variables	<6 hours N=257		6-6.99 hours N=430		7.00-7.99 hours N=434		8.00-8.99 hours N=449		≥9 hours N=114		P-value [a]
Demographic Factors											
Age (years) (mean, SD)	78.78	*4.48*	78.42	*4.61*	78.21	*4.69*	78.67	*4.66*	79.28	*5.08*	0.608
Social Class											
Manual	141	*54.86*	194	*45.12*	170	*39.17*	*193*	*42.98*	61	*53.51*	0.001
Lifestyles											
Smoking Status											
Never smoked	89	*34.63*	159	*36.98*	178	*41.01*	173	*38.53*	39	*34.21*	0.551
Ex-smoker	163	*63.42*	254	*59.07*	240	*55.30*	258	*57.46*	70	*61.40*	
Current smoker	5	*1.95*	17	*3.95*	15	*3.46*	17	*3.79*	5	*4.39*	
Alcohol Intake											
Regularly	81	*31.52*	169	*39.30*	166	*38.25*	159	*35.41*	45	*39.47*	0.274
Not Regularly	134	*52.14*	199	*46.28*	216	*49.77*	228	*50.78*	49	*42.98*	
None	35	*13.62*	52	*12.09*	43	*9.91*	54	*12.03*	19	*16.67*	
Physical activity											
Inactive	129	*50.19*	169	*39.30*	145	*33.41*	161	*35.86*	49	*42.98*	0.002
Active	114	*44.36*	244	*56.74*	266	*61.29*	263	*\58.57*	60	*52.63*	

Unknown	14	*5.45*	17	*3.95*	23	*5.30*	25	*5.57*	5	*4.39*	
General Health measurement											
General Health											
Excellent/Good	132	*51.36*	288	*66.98*	340	*78.34*	335	*74.61*	77	*67.54*	<0.001
Fair	102	*39.69*	127	*29.53*	81	*18.66*	95	*21.16*	34	*29.82*	
Poor	20	*7.78*	11	*2.56*	6	*1.38*	9	*2.00*	2	*1.75*	
Frailty	76	*29.57*	73	*16.98*	47	*10.83*	73	*16.26*	31	*27.19*	<0.001
Disability	124	*48.25*	156	*36.28*	114	*26.27*	137	*30.51*	43	*37.72*	<0.001
Anthropometric and biological measurements											
BMI (kg/m^2)											
≥ 30 (obese)	58	*22.57*	85	*19.77*	77	*17.74*	88	*19.60*	26	*22.81*	0.810
Systolic BP (mmHG) (mean, SD)[b]	145.48	*20.28*	147.09	*18.64*	147.17	*18.68*	145.06	*18.46*	149.69	*23.57*	0.004
FEV_1 (mean, SD)[b]	2.38	*0.54*	2.41	*0.60*	2.45	*0.57*	2.47	*0.56*	2.38	*0.61*	0.327
HDL cholesterol (mean, SD)[b]	1.43	*0.45*	1.48	*0.43*	1.46	*0.42*	1.45	*0.41*	1.37	*0.40*	0.388
Glucose (mean, SD)[b]	5.97	*2.35*	5.72	*1.20*	5.75	*1.52*	5.69	*1.23*	6.00	*1.66*	<0.001
CRP (mean, SD)[b]	3.21	*5.85*	3.69	*13.00*	2.40	*4.02*	2.97	*8.88*	5.38	*16.30*	<0.001
Comorbidities											

CVD	94	*36.58*	138	*32.09*	117	*26.96*	144	*32.07*	42	*36.84*	0.045
Diabetes	42	*16.34*	66	*15.35*	62	*14.29*	63	*14.03*	20	*17.54*	0.838
CKD	10	*3.89*	6	*1.40*	8	*1.84*	6	*1.34*	3	*2.63*	0.140
Cancer	48	*18.68*	74	*17.21*	86	*19.82*	84	*18.71*	21	*18.42*	0.930
Arthritis	136	*52.92*	167	*38.84*	157	*36.18*	139	*30.96*	37	*32.46*	<0.001
Medication use											
Taking antihypertensive medication	174	*68.24*	270	*62.94*	239	*55.45*	265	*59.55*	72	*63.72*	0.013

Data are numbers and percentages unless stated otherwise.

[a] Excludes missing data.

[b] Missing data: 139 for FEV_1, 3 for SBP or DBP, 80 for HDL cholesterol, 181 for glucose and 117 for CRP.

Table 2. Number, rate, and hazard ratios of all-cause, cardiovascular, and non-cardiovascular mortality among older men with different hours of night-time sleep duration

Night-time sleep duration (hours)	Participants (n)	Person years follow-up	Deaths[a] (n)	Rate/100 person-years	Unadjusted HR (95% CI)	Age adjusted HR (95% CI)
All-cause mortality						
<6	257	1793.33	95	5.30	1.15 (0.89-1.49)	1.04 (0.80-1.35)
6-6.99	430	3003.87	147	4.90	1.06 (0.84-1.34)	1.07 (0.85-1.34)
7-7.99	434	3134.45	145	4.63	1.00	1.00
8-8.99	449	3123.18	156	5.00	1.09 (0.87-1.36)	1.04 (0.83-1.30)
≥ 9	114	792.62	39	4.90	1.07 (0.75-1.53)	0.93 (0.65-1.33)
All	***1684***	***11847.46***	***582***	***4.91***		
Cardiovascular mortality						
<6	257	1793.33	33	1.84	**1.66 (1.03-2.67)**	1.49 (0.93-2.41)
6-6.99	430	3003.87	50	1.66	1.50 (0.97-2.30)	1.51 (0.98-2.32)
7-7.99	434	3134.45	35	1.11	1.00	1.00
8-8.99	449	3123.18	43	1.37	1.24 (0.80-1.94)	1.18 (0.76-1.85)
≥ 9	114	792.62	12	1.51	1.37 (0.71-2.63)	1.18 (0.76-1.85)
All	***1684***	***11847.46***	***173***	***1.46***		
Non-cardiovascular mortality						
<6	257	1793.33	62	3.46	0.99 (0.73-1.35)	0.90 (0.66-1.23)
6-6.99	430	3003.87	93	3.10	0.89 (0.67-1.17)	0.89 (0.67-1.17)
7-7.99	434	3134.45	110	3.51	1.00	1.00
8-8.99	449	3123.18	113	3.62	1.04 (0.80-1.35)	0.99 (0.76-1.29)
≥9	114	792.62	27	3.41	0.98 (0.64-1.49)	0.86 (0.56-1.31)
All	***1684***	***11847.46***	***405***	***3.42***		

[a] Chi-square test showed a p-value of 0.917 for all-cause mortality, 0.327 for cardiovascular mortality, and 0.830 for non-cardiovascular mortality among the five levels of night-time sleep duration.

Table 3. Distribution of socio-demographic and characteristics of older men with different hours of daytime napping

Variables	0 hour N=571		<1 hour N=337		1 hour N=400		>1 hour N=160		P-value [a]
Demographic factors									
Age (years) (mean, SD)[c]	78.00	*4.37*	78.24	*4.40*	79.03	*4.85*	80.06	*5.07*	0.021
Social Class									
Manual	257	*45.01*	131	*38.87*	178	*44.50*	81	*50.63*	0.140
Lifestyles									
Smoking Status									
Never smoked	247	*43.26*	136	*40.36*	134	*33.50*	43	*26.88*	0.002
Ex-smoker	308	*53.94*	193	*57.27*	244	*61.00*	108	*67.50*	
Current smoker	16	*2.80*	8	*2.37*	21	*5.25*	9	*5.63*	
Alcohol Intake									
Regularly	210	*36.78*	143	*42.43*	161	*40.25*	42	*26.25*	0.065
Not Regularly	285	*49.91*	154	*45.70*	187	*46.75*	85	*53.13*	
None	68	*11.91*	36	*10.68*	46	*11.50*	24	*15.00*	
Physical activity									
Inactive	183	*32.05*	119	*35.31*	179	*44.75*	93	*58.13*	<0.001
Active	361	*63.22*	200	*59.35*	204	*51.00*	60	*37.50*	

Unknown	27	*4.73*	18	*5.34*	17	*4.25*	7	*4.38*	
General Health measurement									
General Health									
Excellent/Good	430	*75.31*	248	*73.59*	265	*66.25*	78	*48.75*	<0.001
Fair	116	*20.32*	79	*23.44*	113	*28.25*	71	*44.38*	
Poor	13	*2.28*	3	*0.89*	18	*4.50*	10	*6.25*	
Unknown	12	*2.10*	7	*2.08*	4	*1.00*	1	*0.63*	
Frail	82	*14.36*	44	*13.06*	76	*19.00*	59	*36.88*	<0.001
Disability	177	*31.00*	96	*28.49*	149	*37.25*	91	*56.88*	<0.001
Anthropometric and biological measurements									
BMI (kg/m^2)									
≥ 30 (% obese)	87	*15.24*	52	*15.24*	100	*25.00*	52	*32.50*	<0.001
Systolic BP (mmHG) (mean, SD)[b]	146.72	*18.96*	148.22	*19.33*	145.45	*18.96*	143.16	*20.44*	0.654
FEV$_1$(mean, SD)[b]	2.54	*0.57*	2.46	*0.54*	2.34	*0.56*	2.12	*0.56*	0.810
HDL cholesterol (mean, SD)[b]	1.48	*0.43*	1.46	*0.44*	1.42	*0.42*	1.35	*0.37*	0.097
Glucose (mean, SD)[b]	5.64	*1.13*	5.64	*1.20*	5.90	*1.73*	6.36	*2.71*	<0.001
CRP (mean, SD)[b]	2.74	*5.36*	2.58	*4.19*	4.32	*15.4*	5.12	*15.1*	0.003
Comorbidities									

CVD	168	*29.42*	108	*32.05*	126	*31.50*	74	*46.25*	0.001
Diabetes	67	*11.73*	42	*12.46*	81	*20.25*	37	*23.13*	<0.001
CKD	11	*1.93*	4	*1.19*	10	*2.50*	5	*3.13*	0.721
Cancer	104	*18.21*	57	*16.91*	92	*23.00*	36	*22.50*	0.081
Arthritis	207	*36.25*	133	*39.47*	149	*37.25*	72	*45.00*	0.493
Medication use									
Taking antihypertensive medication	324	*56.94*	210	*62.50*	245	*61.71*	119	*74.84*	<0.001

Data are numbers and percentages unless stated otherwise.

[a] Excludes missing data.

[b] Missing data: 127 for FEV_1, 3 for SBP or DBP, 70 for HDL cholesterol, 154 for glucose and 101 for CRP.

Table 4. Number, rate, and hazard ratio of all-cause, cardiovascular, and non-cardiovascular mortality among older men with different hours of daytime napping.

Daytime napping (hours)	Participants (n)	Person years follow-up	Deaths[a] (n)	Rate/100 person-years	Model 1 Unadjusted HR (95%CI) N=1468	Model 2 Age adjusted HR (95%CI) N=1468	Model 3* HR (95%CI)[b] N=1383[*]	Model 4* HR (95%CI)[c] N=1286[*]	Model 5* HR (95%CI)[d] N=1196*
All-cause mortality									
0	571	4188.88	160	3.82	1.00	1.00	1.00	1.00	1.00
<1	337	2459.34	104	4.23	1.12 (0.87-1.42)	1.03 (0.80-1.32)	1.04 (0.81-1.35)	1.00 (0.77-1.31)	0.99 (0.75-1.30)
1	400	2688.95	163	6.06	**1.62 (1.30-2.02)**	**1.45 (1.16-1.80)**	**1.31 (1.04-1.66)**	1.23 (0.97-1.57)	1.21 (0.94-1.56)
>1	160	959.80	89	9.27	**2.57 (1.98-3.34)**	**2.17 (1.68-2.82)**	**1.82 (1.38-2.42)**	**1.53 (1.13-2.06)**	**1.62 (1.18-2.22)**
All	***1468***	***10296.98***	***516***	***5.01***					
Cardiovascular mortality									
0	571	4188.88	48	1.15	1.00	1.00	1.00	1.00	1.00
<1	337	2459.34	31	1.26	1.10 (0.70-1.73)	1.01 (0.64-1.69)	0.97 (0.60-1.56)	0.80 (0.48-1.33)	0.83 (0.49-1.41)
1	400	2688.95	51	1.90	**1.68 (1.13-2.49)**	1.47 (0.99-2.19)	1.32 (0.87-2.01)	1.10 (0.70-1.74)	1.12 (0.69-1.80)
>1	160	959.80	25	2.60	**2.37 (1.46-3.84)**	**1.94 (1.20-3.16)**	1.52 (0.89-2.59)	1.23 (0.71-2.15)	1.26 (0.69-2.28)

All	***1468***	***10296.98***	***155***	***1.51***					
Non-cardiovascular mortality									
0	571	4188.88	112	2.67	1.00	1.00	1.00	1.00	1.00
<1	337	2459.34	71	2.89	1.08 (0.80-1.46)	1.01 (0.75-1.36)	1.05 (0.77-1.42)	1.07 (0.78-1.47)	1.04 (0.75-1.45)
1	400	2688.95	110	4.09	**1.57 (1.21-2.04)**	**1.41 (1.08-1.84)**	1.28 (0.97-1.70)	1.27 (0.94-1.70)	1.22 (0.90-1.66)
>1	160	959.80	64	6.67	**2.67 (1.96-3.63)**	**2.28 (1.67-3.10)**	**1.96 (1.41-2.74)**	**1.66 (1.16-2.38)**	**1.77 (1.22-2.57)**
All	***1468***	***10296.98***	***357***	***3.47***					

[a] Chi-square test showed a p-value of <0.001 for differences in mortality rate among four levels of daytime napping.

[b.] Model 3 adjusts for age, smoking, physical activity, and BMI.

[c] Model 4 adjusts for covariates in model 3 and CVD, diabetes, frailty, general health, antihypertensive medication.

[d] Model 5 adjusts for covariates in model 4 and CRP.

*Numbers of participants analysed in Models 3-5 were different from Models 1-2. The total number of participants in Model 3 was 1383, in Model 4 was 1286, and in Model 5 was 1196 for analysis. This is due to excluding missing data from covariates (i.e., smoking, physical activity, BMI, CVD, diabetes, frailty, general health, blood pressure lowering medication, and CRP) in each model adjusted for.

APPENDIX

Appendix Table 1. ***Sensitivity analysis (n=1196):*** **Number, rate, and hazard ratios of all-cause, cardiovascular, and non-cardiovascular mortality among older men with different hours of daytime napping.**

Daytime napping (hours)	Participants (n)	Person years follow-up	Deaths (n)	Rate/100 person years	Unadjusted HR (95%CI)	Age adjusted HR (95%CI)	Model 3 HR (95%CI) [b]	Model 4 HR (95%CI) [c]	Model 5 HR (95%CI) [d]
All-cause mortality									
0	477	3515.04	130	3.70	1.00	1.00	1.00	1.00	1.00
<1	282	2059.32	84	4.10	1.11 (0.84-1.46)	1.03 (0.78-1.36)	1.00 (0.76-1.32)	0.99 (0.75-1.30)	0.99 (0.75-1.30)
1	317	2162.87	124	5.73	**1.59 (1.24-2.03)**	**1.41 (1.10-1.80)**	**1.29 (1.01-1.66)**	1.22 (0.95-1.58)	1.21 (0.94-1.56)
>1	120	731.70	65	8.88	**2.57 (1.90-3.46)**	**2.17 (1.61-2.93)**	**1.82 (1.34-2.48)**	**1.62 (1.18-2.21)**	**1.62 (1.18-2.22)**
All	*1196*	*8468.93*	*403*	4.76					
Cardiovascular mortality									
0	477	3515.04	39	1.12	1.00	1.00	1.00	1.00	1.00
<1	282	2059.32	22	1.11	0.96 (0.57-1.63)	0.89 (0.53-1.51)	0.85 (0.50-1.44)	0.83 (0.49-1.41)	0.83 (0.49-1.41)
1	317	2162.87	35	1.62	1.48 (0.94-2.34)	1.30 (0.82-2.05)	1.16 (0.73-1.85)	1.12 (0.70-1.79)	1.12 (0.69-1.80)
>1	120	731.70	18	2.46	**2.32 (1.33-4.06)**	**1.93 (1.10-3.38)**	1.53 (0.85-2.73)	1.26 (0.69-2.28)	1.26 (0.69-2.28)

All	*1196*	*8468.93*	*114*	1.35					
Non-cardiovascular mortality									
0	477	3515.04	91	2.59	1.00	1.00	1.00	1.00	1.00
<1	282	2059.32	61	2.96	1.15 (0.83-1.59)	1.08 (0.78-1.49)	1.05 (0.76-1.45)	1.04 (0.75-1.45)	1.04 (0.75-1.45)
1	317	2162.87	87	4.02	**1.60 (1.19-2.15)**	**1.42 (1.06-1.91)**	1.32 (0.98-1.78)	1.24 (0.92-1.68)	1.22 (0.90-1.66)
>1	120	731.70	47	6.42	**2.67 (1.88-3.80)**	**2.27 (1.59-3.24)**	**1.95 (1.36-2.81)**	**1.77 (1.22-2.56)**	**1.77 (1.22-2.57)**
All	*1196*	*8468.93*	*357*	3.34					

[a] Chi-square test showed a p-value of <0.001 for differences in mortality rate among four levels of daytime napping.
[b.] Model 3 adjusts for age, smoking, physical activity, and BMI.
[c] Model 4 adjusts for covariates in model 3 and CVD, diabetes, frailty, general health, antihypertensive medication.
[d] Model 5 adjusts for covariates in model 4 and CRP.