



ORIGINAL ARTICLE

Sleep lengthening in late adulthood signals increased risk of mortality

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Abstract

Study Objectives: Epidemiological evidence indicates that both short and long sleep at midlife increase mortality risk, but few studies have examined how change in sleep duration between midlife and later life affects this risk. We examined the association between change in sleep duration and mortality risk.

Methods: The Singapore Chinese Health Study is a prospective cohort of 63257 Chinese in Singapore aged 45–74 years at recruitment (1993–1998). Self-reported sleep duration was collected from 39523 participants who completed both baseline (mean age 54.8 years) and follow-up II (mean age 67.9 years; 2006–2010) interviews, which were on average 12.7 years apart. Mortality data were obtained via linkage with national death registry up to December 31, 2015.

Results: Compared with participants who reported sleeping the recommended duration (7 hr) at both interviews, those with persistently short sleep (≤ 5 hr) had increased risk of all-cause mortality (hazard ratio [HR] 1.27, 95% confidence interval [CI] 1.06–1.53). Similarly, those with persistently long sleep (≥ 9 hr) had increased risk of all-cause (HR 1.47, 95% CI 1.24–1.73) and cardiovascular (HR 1.40, 95% CI 1.04–1.89) mortality. The proportion of long-sleepers increased with aging (6%–23.7%). Progression to long sleep from short (HR 1.50, 95% CI 1.24–1.81) or recommended (HR 1.43, 95% CI 1.25–1.64) duration was associated with increased all-cause mortality, especially for cardiovascular mortality. Change in sleep duration was not linked to cancer mortality.

Conclusions: Persistent short or long sleep or increasing sleep duration in late adulthood was associated with increased risk of all-cause mortality, especially from cardiovascular causes.

Statement of Significance

Although the association between sleep duration and mortality has widely been examined, sleep patterns can change with advancing age and few studies have examined how a change in sleep duration affects mortality risk. Furthermore, the relation between change in sleep duration and cause of death has not been studied. The present study found that compared with those able to maintain the recommended sleep duration of 7 hr, persistent short sleep was associated with increased risk of all-cause mortality, whereas persistent long sleep or an increase in long sleep duration increased the risk of all-cause and cardiovascular mortality. These findings reiterate the benefit of being able to maintain the recommended duration of sleep through to later life.

Key words: sleep duration; sleep change; mortality

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Introduction

Sleep duration is associated with mortality as well as risk of cardiovascular, cerebrovascular disease, obesity, diabetes mellitus, cancer, and cognitive decline [1–3]. Many studies have reported a U-shape association between habitual sleep duration and mortality [4–8], and recent meta-analyses have concluded that both short and long sleep durations are associated with increased risk of all-cause mortality [9–11] and cardiovascular mortality [10]. However, in most studies, sleep duration was collected at a single time point, and sleep patterns can change with advancing age [12]. A longitudinal study that examined the change of sleep duration assessed at two different time points reported a U-shape association between sleep duration at both time points and total mortality, the association being stronger at the second time point [13]. Although both increased and decreased sleep durations over time were associated with increased risk of all-cause mortality [13], a finer grained account of how much sleep duration changed was not available. Another recent study [14] reported that either progression from short to long sleep or reduction from long to short sleep was associated with higher risk of all-cause mortality. However, this study did not examine cause-specific mortality [14].

Utilizing the longitudinal Singapore Chinese Health Study, we examined the association between changes in sleep duration over about 13 years and risk of all-cause mortality, as well as risk of cardiovascular disease (CVD), ischaemic heart disease (IHD), stroke, and cancer mortality.

Methods

Study population

The Singapore Chinese Health Study consists of 63257 Chinese adults aged 45–74 years recruited between April 1993 and December 1998 [15]. Enrolled participants were citizens or permanent residents of Singapore residing in public housing estates, and they belonged to the two major dialect groups of Chinese in Singapore—the Hokkiens who originated from the southern part of Fujian Province and the Cantonese who came from the central region of Guangdong Province. Follow-up I and follow-up II interviews of surviving participants of the study were conducted from 1999 to 2004 and 2006 to 2010, respectively. Information on sleep duration was collected at both baseline and follow-up II interviews. This study was approved by the Institutional Review Boards at the National University of Singapore and the University of Pittsburgh, and all study participants gave informed consent.

Assessment of sleep duration and covariates

At recruitment, an in-person interview was conducted using a structured questionnaire to elicit information such as the participants' demographics, sleep duration, height and weight, usual physical activity, alcohol intake, lifetime use of tobacco, and history of physician-diagnosed medical conditions such as hypertension, IHD, stroke, diabetes, and cancer. History of cancer prior to the participation to the study included self-reported cases at baseline interview, as well as cases identified via linkage analysis with the National Cancer Registry of Singapore, to ensure a comprehensive capture of cancer cases that could have occurred before the establishment of the registry in 1968. Height

and weight were used to calculate body mass index as weight in kilograms divided by height in meters squared. The usual sleep duration of the participants was assessed by asking the question “On the average, during the last year, how many hours in a day did you sleep?”, with the following response categories: 5 hr or less, 6 hr, 7 hr, 8 hr, 9 hr, and 10 hr or more. Information on sleep duration, tobacco use, physical activity, alcohol intake, and medical history was updated at follow-up II that was administered on average 12.7 (standard deviation [SD] 1.9; range 7.7–17.2) years after the baseline interview.

Ascertainment of mortality

Information on date and cause of death among all cohort participants was obtained through linkage analysis with the Singapore Registry of Births and Deaths after their enrolment into the study up to December 31, 2015. The International Classification of Diseases version 9 codes [16] were recorded in the registry. The primary cause of death was used for the analysis, and the end points in our cause-specific analyses were deaths from CVD (codes 390–459), IHD (codes 410–414), stroke (codes 430–438), and all cancers (codes 140–208).

Statistical analysis

Only participants who completed both the baseline and follow-up II interviews were included in the analysis ($n = 39523$). Daily sleep duration was categorized in both baseline and follow-up II questionnaires as ≤ 5 , 6, 7, 8, and ≥ 9 hr. The characteristics of the study participants by sleep duration categories at baseline and follow-up II, respectively, were compared using analysis of variance (ANOVA) for continuous variables or chi-square test for categorical variables.

For each participant eligible for the present analysis, the person-year at risk was calculated from date of follow-up II interview to date of death or December 31, 2015. Cox proportional hazards models were used to estimate the hazard ratio (HR) and corresponding 95% confidence intervals (CIs) for mortality associated with different sleep duration categories compared with 7 hr of sleep per day as the reference category. The choice of reference group was based on the recommended sleep duration for healthy older adults by the American Academy of Sleep Medicine and Sleep Research Society [17]. The first Cox regression model was adjusted for age (years), year of recruitment (1993–1995, 1996–1998), gender, dialect group (Hokkien, Cantonese), total weekly duration on moderate or strenuous physical activity (<0.5 , 0.5–4, ≥ 4 hr per week), level of education (no formal education, primary school, secondary school, or higher), smoking status (never, former, current), alcohol intake (none, weekly, daily), and body mass index (<20 , 20– <24 , 24– <28 , ≥ 28 kg/m²). In the second model, we additionally adjusted for history of medical conditions including hypertension, IHD, stroke, diabetes, and cancer. The proportional hazards assumption of the Cox models was assessed by including a time-dependent covariate for the variable of sleep duration in the model, and we did not observe any violation of the assumption.

The sleep durations reported at baseline and follow-up II interviews were categorized into “recommended,” “short,” or “long” before we examined the relation between change in category of sleep duration and mortality risk. Recommended sleep duration was defined as 7 hr of sleep, whereas ≤ 5 and ≥ 9 hr were

labeled short and long sleep durations, respectively. Participants who reported 6 or 8 hr of sleep were excluded from this analysis to allow for a clearer demarcation among short, recommended, and long sleep durations. Kaplan–Meier survival curves were used to examine the association between change in sleep duration between baseline and follow-up II and all-cause mortality. Cox proportional hazards models were then used to evaluate the association between change in sleep duration and risk of all-cause, CVD, IHD, stroke, and cancer mortality.

Kaplan–Meier survival analysis was performed using STATA 13.0 (College Station, Texas). All other statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC) statistical software package, and two-sided *p*-values of <0.05 were considered statistically significant.

Results

The present analysis included 39 523 who completed follow-up II interview. The cutoff date of the present analysis was December 31, 2015. Among the 39 523 participants, 5610 deaths occurred from the time of follow-up II interview to the cutoff date and were included in the present analysis with a mean duration of follow-up for all participants being 7.1 (SD 1.7) years. The mean age of death was 78.0 (SD 7.8) years. Of the 5610 deaths, 1690 (30.1%) died from CVD, including 927 (16.5%) from IHD, 446 (8%) from stroke, and 1989 (35.5%) died from cancer.

At baseline interview, 33.9% reported sleeping the recommended duration (7 hr), 9.1% reported short (≤ 5 hr), and 6% reported long (≥ 9 hr) sleep duration. At follow-up II, which was after an average of 12.7 (SD 1.9) years from baseline, 23.9% reported recommended sleep duration, 10.8% reported short sleep, and 23.7% reported long sleep, indicating a small increase in proportion of short sleepers and a large increase in proportion of long sleepers at follow-up II compared with baseline. Among those who reported recommended sleep duration at baseline, 47.8% maintained the same duration of sleep, whereas 14.4% became short sleepers and 37.7% became long sleepers. Among those who reported short sleep at baseline, 44.4% remained short sleepers at follow-up II, whereas 29.5% reported recommended sleep duration and 26% became long sleepers. Among those who reported long sleep at baseline, 70.8% remained long sleepers, whereas 21.8% reduced to recommended sleep and 7.4% became short sleepers (Table 1).

When we examined the characteristics of participants by their sleep duration at baseline or follow up II, we observed that participants who reported ≤ 5 or ≥ 9 hr of sleep at baseline or follow-up II were older, more likely to be physically inactive (<0.5 hr of moderate or vigorous physical activities weekly), and had a higher prevalence of hypertension, IHD, stroke, and diabetes compared with those who reported 7 hr of sleep (Supplementary Tables 1 and 2). Long sleep duration was also associated with higher prevalence of cancer at follow-up II. In addition, long sleep duration was more likely to be reported by current smokers at both baseline and follow-up II (Supplementary Tables 1 and 2). Comparing all the categories of sleep change, participants who reported recommended sleep duration at both baseline and follow-up II were the youngest, more likely to be men and received higher level of education, less likely to be physically inactive, and had the lowest prevalence of hypertension, IHD, stroke, diabetes, and cancer (Table 1). Short sleepers at

baseline who increased to long sleep at follow-up II were the oldest, most likely to be physically inactive, and had the highest prevalence of hypertension and stroke compared with other sleep change categories (Table 1).

The mean duration from baseline interview and time of death for the 5610 participants who died was 17.1 (SD 2.7) years. A U-shape association was observed between baseline sleep duration and all-cause mortality. Further adjustment for history of comorbidities in the statistical models gave similar results, although we observed a slight attenuation of the risk estimates for all-cause, CVD, IHD, and stroke mortality. In the final-adjusted model, there was a statistically significant increased risk of all-cause mortality with ≤ 5 hr (HR 1.12, 95% CI 1.02–1.23) and ≥ 9 hr (HR 1.14, 95% CI 1.03–1.27) compared with 7 hr of sleep reported at baseline (Table 2). A similar trend was observed for all the specific causes of death even though most of the associations did not reach statistical significance. A statistically significant result was observed only for the association between ≤ 5 hr of sleep and cancer mortality (HR 1.22, 95% CI 1.04–1.42) (Table 2). The U-shape association was also observed between sleep duration reported at follow-up II and all-cause mortality, and the risk estimate of all-cause mortality associated with ≥ 9 hr of sleep at follow-up II was higher than that associated with ≥ 9 hr of sleep at baseline. Compared with participants who reported 7 hr of sleep at follow-up II, ≤ 5 hr of sleep at follow-up II was associated with all-cause (HR 1.11, 95% CI 1.01–1.23) and CVD mortality (HR 1.27, 95% CI 1.05–1.52), whereas ≥ 9 hr of sleep was associated with increased all-cause (HR 1.35, 95% CI 1.25–1.46), CVD (HR 1.50, 95% CI 1.30–1.73), IHD (HR 1.32, 95% CI 1.09–1.59), stroke (HR 1.77, 95% CI 1.33–2.35), and cancer mortality (HR 1.13, 95% CI 1.00–1.29) (Table 3).

Figure 1 shows the Kaplan–Meier survival curves among categories of change in sleep that were significantly different from those who maintained recommended sleep duration at both baseline and follow-up II. This latter category had the highest survival rate, whereas persons who reported increased sleep from short to long duration had the lowest survival. Compared with participants with consistently recommended sleep duration, those who had reported persistently short or long sleep duration at baseline and follow-up II, as well as those who had increased their sleep from recommended to long duration, also had lower survival rates (Figure 1).

Compared with participants who maintained recommended sleep duration at both baseline and follow-up II, persistently short sleep duration was associated with higher risk of all-cause (HR 1.27, 95% CI 1.06–1.53), whereas persistently long sleep duration was associated with higher risk of all-cause (HR 1.47, 95% CI 1.24–1.73), CVD (HR 1.40, 95% CI 1.04–1.89), and stroke mortality (HR 1.84, 95% CI 1.07–3.16) (Table 4). Higher risk of CVD mortality was also observed when sleep was increased from short (HR 1.42, 95% CI 1.01–2.00) or recommended (HR 1.53, 95% CI 1.20–1.95) duration at baseline to long sleep at follow-up II. Cancer mortality was not significantly associated with change in sleep duration. There was no significant increase in risk of mortality when participants who were short or long sleepers at baseline changed to have recommended sleep duration at follow-up II (Table 4). We have further examined the relation between sleep change and mortality with stratification by age group (<70 or ≥ 70 years at follow-up II), history of medical conditions including hypertension, IHD, stroke, diabetes and cancer (yes to any of the conditions or none of the conditions), and smoking status (never

Table 1. Characteristics of study participants at follow-up II interview by change in sleep duration from baseline (1993–1998) to follow-up II (2006–2010), the Singapore Chinese Health Study

Change in sleep duration										
Baseline	Short (≤ 5 hr)			Recommended (7 hr)			Long (≥ 9 hr)			
Follow-up II	Short	7 hr	Long	Short	7 hr	Long	Short	7 hr	Long	P*
N	1054	701	618	1104	3659	2885	114	334	1085	
Age, years	68.8 \pm 7.7	69.2 \pm 7.3	73.4 \pm 7.7	67.6 \pm 7.2	66.2 \pm 6.7	70.7 \pm 7.5	70.3 \pm 9.0	66.5 \pm 6.7	71.0 \pm 7.7	<0.001
Body mass index, kg/m ²	23.1 \pm 3.6	23.2 \pm 3.6	23.1 \pm 3.5	23.3 \pm 3.6	23.2 \pm 3.3	23.3 \pm 3.6	23.1 \pm 4.0	23.1 \pm 3.7	23.1 \pm 3.6	0.73
Men	374 (35.5)	235 (33.5)	210 (34.0)	411 (37.2)	1580 (43.2)	1190 (41.3)	46 (40.4)	125 (37.4)	443 (40.8)	<0.001
Dialect group										<0.001
Cantonese	512 (48.6)	379 (54.1)	327 (52.9)	465 (42.1)	1880 (51.4)	1396 (48.4)	54 (47.4)	172 (51.5)	568 (52.4)	
Hokkien	542 (51.4)	322 (45.9)	291 (47.1)	639 (57.9)	1779 (48.6)	1489 (51.6)	60 (52.6)	162 (48.5)	517 (47.7)	
Moderate of vigorous physical activity, hr/week										<0.001
<0.5	91 (8.6)	57 (8.1)	110 (17.8)	73 (6.6)	249 (6.8)	365 (12.7)	17 (14.9)	31 (9.3)	168 (15.5)	
0.5–4	127 (12.1)	77 (11.0)	128 (20.7)	165 (15.0)	559 (15.3)	555 (19.2)	21 (18.4)	51 (15.3)	193 (17.8)	
≥ 4	836 (79.3)	567 (80.9)	380 (61.5)	866 (78.4)	2851 (77.9)	1965 (68.1)	76 (66.7)	252 (75.5)	724 (66.7)	
Level of education										<0.001
No formal education	286 (27.1)	225 (32.1)	251 (40.6)	285 (25.8)	670 (18.3)	902 (31.3)	38 (33.3)	70 (21.0)	335 (30.9)	
Primary school	473 (44.9)	308 (43.9)	285 (46.1)	482 (43.7)	1580 (43.2)	1368 (47.4)	53 (46.5)	152 (45.5)	511 (47.1)	
Secondary school or higher	295 (28.0)	168 (24.0)	82 (13.3)	337 (30.5)	1409 (38.5)	615 (21.3)	23 (20.2)	112 (33.5)	239 (22.0)	
Smoking status										<0.001
Never	772 (73.2)	504 (71.9)	422 (68.3)	800 (72.5)	2673 (73.1)	1956 (67.8)	80 (70.2)	240 (71.9)	708 (65.3)	
Former	177 (16.8)	107 (15.3)	132 (21.4)	180 (16.3)	594 (16.2)	575 (19.9)	17 (14.9)	60 (18.0)	215 (19.8)	
Current	105 (10.0)	90 (12.8)	64 (10.4)	124 (11.2)	392 (10.7)	354 (12.3)	17 (14.9)	34 (10.2)	162 (14.9)	
Alcohol intake										<0.001
None	967 (91.8)	642 (91.6)	579 (93.7)	1029 (93.2)	3298 (90.1)	2682 (93.0)	104 (91.2)	300 (89.8)	981 (90.4)	
Weekly	57 (5.4)	46 (6.6)	20 (3.2)	52 (4.7)	278 (7.6)	132 (4.6)	7 (6.1)	24 (7.2)	64 (5.9)	
Daily	30 (2.9)	13 (1.9)	19 (3.1)	23 (2.1)	83 (2.3)	71 (2.5)	3 (2.6)	10 (3.0)	40 (3.7)	
Comorbidities										
Hypertension	568 (53.9)	378 (53.9)	404 (65.4)	608 (55.1)	1902 (52.0)	1701 (59.0)	69 (60.5)	185 (55.4)	637 (58.7)	<0.001
Ischaemic heart disease	98 (9.3)	45 (6.4)	62 (10.0)	78 (7.1)	187 (5.1)	251 (8.7)	12 (10.5)	25 (7.5)	76 (7.0)	<0.001
Stroke	48 (4.6)	26 (3.7)	55 (8.9)	53 (4.8)	92 (2.5)	202 (7.0)	8 (7.0)	15 (4.5)	69 (6.4)	<0.001
Diabetes	238 (22.6)	144 (20.5)	169 (27.4)	231 (20.9)	632 (17.3)	697 (24.2)	29 (25.4)	75 (22.5)	298 (27.5)	<0.001
Cancer	92 (8.7)	47 (6.7)	60 (9.7)	93 (8.4)	227 (6.2)	269 (9.3)	12 (10.5)	31 (9.3)	88 (8.1)	<0.001

*p-Value by ANOVA (continuous variables) or χ^2 -test (categorical variables).

or ever smokers), and similar risk estimates were obtained (Supplementary Table 3). In the stratified analysis, an increase from 7 hr to long sleep duration was associated with statistically significant increased risk of all-cause mortality regardless of age group, history of medical conditions, or smoking status (Supplementary Table 3). Persistently long sleep duration was associated with increased risk of all-cause mortality regardless of age group, history of medical conditions, or smoking status, although the increased mortality risk among ever smokers was of borderline significance (Supplementary Table 3). We have repeated the analysis for sleep duration at baseline using the entire cohort and the results were essentially the same as the results using 39523 participants included in this study. Specifically, compared with 7 hr of sleep, there was a statistically significant increased risk of CVD (HR 1.19, 95% CI 1.10–1.30) and cancer (HR 1.15, 95% CI 1.06–1.25) mortality with ≤ 5 hr, and increased risk of CVD (HR 1.22, 95% CI 1.12–1.34) and cancer (HR 1.09, 95% CI 0.99–1.20) mortality with ≥ 9 hr of sleep. This shows that the results from the smaller subcohort in this study were comparable to the entire cohort.

Discussion

The present study found that compared with those with a consistent sleep duration of 7 hr, persistent short sleep was associated with increased risk of all-cause mortality, whereas persistent long sleep or an increase in long sleep duration in late adulthood increased the risk of all-cause and cardiovascular mortality.

The association between sleep duration and mortality has been examined by many studies, and our observation of a U-shape association between sleep duration and all-cause mortality with a nadir at 7 hr at baseline and follow-up II is consistent with current literature [4, 7–9, 11]. Both short and long sleep have been reported by epidemiological studies to be associated with higher risk of cardiovascular outcome and mortality [4, 6, 7, 18]. Insufficient and prolonged sleep duration have been associated with cardiovascular risk factors such as metabolic syndrome, obesity, hypertension, insulin resistance, and type II diabetes [19]. In our cohort, we also observed higher prevalence of comorbidities such as hypertension, IHD, stroke, and diabetes mellitus among short and long sleepers. Short sleep duration

Table 2. Adjusted hazard ratios for sleep duration at baseline (1993–1998) and mortality, the Singapore Chinese Health Study

Cause of death	Sleep duration at baseline				
	≤5 hr	6 hr	7 hr	8 hr	≥9 hr
All-cause					
No. of deaths	641	1285	1736	1514	434
Model 1 [†]	1.14 (1.04–1.25)	0.99 (0.92–1.07)	1.00 (referent)	1.06 (0.98–1.13)	1.18 (1.06–1.31)
Model 2 [‡]	1.12 (1.02–1.23)	0.99 (0.92–1.06)	1.00 (referent)	1.05 (0.98–1.12)	1.14 (1.03–1.27)
Cardiovascular					
No. of deaths	191	380	538	449	132
Model 1 [†]	1.11 (0.94–1.31)	0.95 (0.83–1.08)	1.00 (referent)	1.01 (0.89–1.15)	1.17 (0.96–1.41)
Model 2 [‡]	1.08 (0.91–1.27)	0.95 (0.83–1.08)	1.00 (referent)	1.00 (0.88–1.14)	1.11 (0.92–1.34)
Ischemic heart disease					
No. of deaths	95	224	289	254	65
Model 1 [†]	1.06 (0.84–1.34)	1.06 (0.89–1.26)	1.00 (referent)	1.07 (0.90–1.26)	1.08 (0.83–1.42)
Model 2 [‡]	1.03 (0.81–1.30)	1.05 (0.88–1.24)	1.00 (referent)	1.06 (0.89–1.25)	1.02 (0.77–1.33)
Stroke					
No. of deaths	56	90	143	119	38
Model 1 [†]	1.14 (0.83–1.56)	0.83 (0.63–1.08)	1.00 (referent)	1.01 (0.79–1.29)	1.24 (0.86–1.77)
Model 2 [‡]	1.12 (0.82–1.53)	0.83 (0.64–1.08)	1.00 (referent)	1.00 (0.78–1.27)	1.19 (0.83–1.70)
Cancer					
No. of deaths	226	465	611	554	133
Model 1 [†]	1.22 (1.04–1.42)	1.04 (0.92–1.17)	1.00 (referent)	1.10 (0.98–1.24)	1.07 (0.89–1.29)
Model 2 [‡]	1.22 (1.04–1.42)	1.04 (0.92–1.17)	1.00 (referent)	1.10 (0.98–1.24)	1.07 (0.88–1.29)

[†]Model 1 adjusted for age (years), year of recruitment (1993–1995 and 1996–1998), gender, dialect group (Hokkien and Cantonese), physical activity (<0.5, 0.5–4, and ≥4 hr/week), level of education (no formal education, primary school, secondary school, or higher), smoking status (never, former, and current), alcohol intake (none, weekly, and daily), and body mass index (<20, 20–<24, 24–<28, and ≥28 kg/m²).

[‡]Model 2 further adjusted for history of hypertension, ischaemic heart disease, stroke, diabetes, and cancer.

Table 3. Adjusted hazard ratios for sleep duration at follow-up II (2006–2010) and mortality, the Singapore Chinese Health Study

Cause of death	Sleep duration at follow-up II				
	≤5 hr	6 hr	7 hr	8 hr	≥9 hr
All-cause					
No. of deaths	582	681	994	1256	2097
Model 1 [†]	1.14 (1.03–1.26)	1.04 (0.94–1.15)	1.00 (referent)	1.09 (1.00–1.19)	1.40 (1.30–1.51)
Model 2 [‡]	1.11 (1.01–1.23)	1.04 (0.94–1.14)	1.00 (referent)	1.08 (0.99–1.17)	1.35 (1.25–1.46)
Cardiovascular					
No. of deaths	191	191	282	360	666
Model 1 [†]	1.33 (1.11–1.60)	1.03 (0.85–1.23)	1.00 (referent)	1.11 (0.95–1.29)	1.57 (1.36–1.81)
Model 2 [‡]	1.27 (1.05–1.52)	1.03 (0.86–1.24)	1.00 (referent)	1.08 (0.93–1.27)	1.50 (1.30–1.73)
Ischemic heart disease					
No. of deaths	103	102	169	210	343
Model 1 [†]	1.22 (0.95–1.56)	0.91 (0.71–1.16)	1.00 (referent)	1.09 (0.89–1.33)	1.38 (1.14–1.66)
Model 2 [‡]	1.15 (0.90–1.48)	0.92 (0.72–1.18)	1.00 (referent)	1.06 (0.87–1.30)	1.32 (1.09–1.59)
Stroke					
No. of deaths	39	51	67	91	198
Model 1 [†]	1.12 (0.75–1.66)	1.16 (0.81–1.67)	1.00 (referent)	1.16 (0.85–1.60)	1.92 (1.45–2.55)
Model 2 [‡]	1.06 (0.71–1.57)	1.16 (0.80–1.66)	1.00 (referent)	1.13 (0.82–1.55)	1.77 (1.33–2.35)
Cancer					
No. of deaths	191	270	415	477	636
Model 1 [†]	0.94 (0.79–1.11)	0.97 (0.83–1.13)	1.00 (referent)	1.03 (0.90–1.18)	1.16 (1.02–1.32)
Model 2 [‡]	0.93 (0.78–1.10)	0.97 (0.83–1.12)	1.00 (referent)	1.03 (0.90–1.17)	1.13 (1.00–1.29)

[†]Model 1 adjusted for age (years), year of recruitment (1993–1995 and 1996–1998), gender, dialect group (Hokkien and Cantonese), physical activity (<0.5, 0.5–4, and ≥4 hr/week), level of education (no formal education, primary school, secondary school, or higher), smoking status (never, former, and current), alcohol intake (none, weekly, and daily), and body mass index (<20, 20–<24, 24–<28, and ≥28 kg/m²).

[‡]Model 2 further adjusted for history of hypertension, ischaemic heart disease, stroke, diabetes, and cancer.

may lead to adverse cardiovascular outcomes via mechanisms such as changes in production of leptin and ghrelin, leading to increased energy intake, obesity, and impaired glycemic control, increased secretion of the stress hormone cortisol and altered growth hormone metabolism, and the activation of

low-grade inflammation [18]. On the other hand, the underlying mechanism(s) underlying long sleep duration and poorer cardiovascular outcomes is less clear, and possible explanations include the effects of sleep fragmentation, depression, low level of physical activity, and undiagnosed health conditions [18, 20].

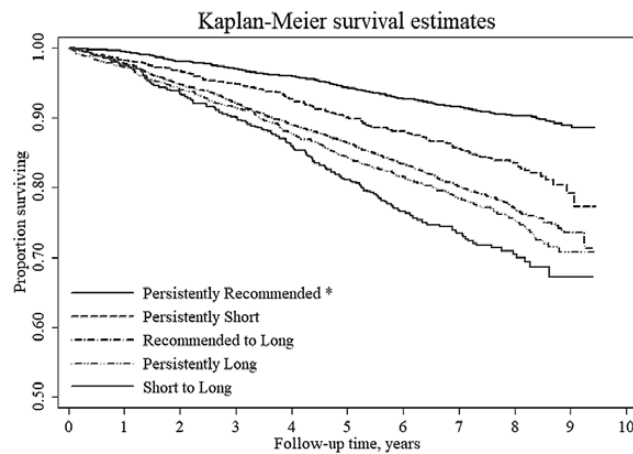


Figure 1. Kaplan-Meier survival curves for all-cause mortality by change in sleep duration from baseline (1993–1998) to follow-up II (2006–2010), the Singapore Chinese Health Study.

Table 4. Adjusted hazard ratios for change in sleep duration from baseline (1993–1998) to follow-up II (2006–2010) and mortality, the Singapore Chinese Health Study

Change in sleep duration from baseline to follow-up II									
Baseline	Short (≤ 5 hr)			Recommended (7 hr)			Long (≥ 9 hr)		
Follow-up II	Short	Recommended	Long	Short	Recommended	Long	Short	Recommended	Long
All-cause									
No. of deaths	170	102	173	145	344	623	23	37	259
Hazard ratio [†]	1.27	1.14	1.50	1.16	1.00	1.43	1.00	0.99	1.47
95% CI [†]	1.06–1.53	0.91–1.43	1.24–1.81	0.95–1.41	Referent	1.25–1.64	0.65–1.54	0.71–1.40	1.24–1.73
Cardiovascular									
No. of deaths	56	29	53	47	107	218	9	12	78
Hazard ratio [†]	1.33	1.05	1.42	1.19	1.00	1.53	1.20	0.99	1.40
95% CI [†]	0.96–1.84	0.69–1.59	1.01–2.00	0.84–1.68	Referent	1.20–1.95	0.60–2.40	0.54–1.79	1.04–1.89
Ischemic heart disease									
No. of deaths	27	15	27	27	62	114	4	7	34
Hazard ratio [†]	1.17	0.97	1.38	1.20	1.00	1.44	0.97	1.02	1.10
95% CI [†]	0.74–1.84	0.55–1.71	0.86–2.22	0.76–1.89	Referent	1.04–1.98	0.35–2.71	0.47–2.24	0.72–1.70
Stroke									
No. of deaths	15	10	18	10	28	62	0	3	28
Hazard ratio [†]	1.27	1.33	1.64	0.93	1.00	1.54	—	0.95	1.84
95% CI [†]	0.67–2.40	0.64–2.76	0.88–3.05	0.45–1.92	Referent	0.97–2.44	—	0.29–3.15	1.07–3.16
Cancer									
No. of deaths	52	40	52	45	144	180	3	13	73
Hazard ratio [†]	1.01	1.16	1.37	0.90	1.00	1.15	0.38	0.90	1.17
95% CI [†]	0.73–1.40	0.81–1.65	0.98–1.90	0.64–1.26	Referent	0.92–1.45	0.12–1.19	0.51–1.58	0.88–1.57

[†]Model 1 adjusted for age (years), year of recruitment (1993–1995 and 1996–1998), gender, dialect group (Hokkien and Cantonese), physical activity (<0.5, 0.5–4, and ≥ 4 hr/week), level of education (no formal education, primary school, secondary school, or higher), smoking status (never, former, and current), alcohol intake (none, weekly, and daily), body mass index (<20, 20–<24, 24–<28, and ≥ 28 kg/m²), history of hypertension, ischaemic heart disease, stroke, diabetes, and cancer.

In our study, cancer mortality was not associated with change in sleep duration. This is consistent with the results of two recent meta-analyses [21, 22], in which neither short nor long sleep duration was associated with increased risk of cancer. These two meta-analyses [21, 22] also reported long sleep duration to be positively associated with colorectal cancer but inversely associated with hormone-related cancers such as prostate and ovarian cancer. However, we were unable to examine cancer mortality by the different cancer types in our analysis. These findings collectively reflect the lack of consensus in linking sleep duration with cancer risk reflected in epidemiological data [17, 21, 22].

Change in sleep duration has been reported to be associated with higher risk of all-cause mortality [5, 13, 14]. Persistently short and long sleep durations have been reported to be associated with increased risk of all-cause mortality among men in the Finnish Twin Cohort [5], and this is in line with the results of the present study. A recent study conducted in a smaller cohort concluded that there was no association between persistent short or long sleep and risk of mortality [14], although the authors had reported a slight increase in these risk estimates compared with the reference group of consistent 7–8 hr of sleep. One of these studies had examined cause-specific mortality, and the authors reported higher risk of CVD mortality among men to

be associated with reduction of sleep duration from 6, 7, or 8 hr, but the association with increased sleep duration was not statistically significant [13]. Conversely, we found that the transition to long sleep at late adulthood was associated with greater risk of CVD mortality, but the association with shortening sleep was not significant.

Although persistently short sleep has been observed to increase the risk of all-cause mortality in other studies and our cohort, we did not observe an increased risk of mortality with reduction of sleep duration in this cohort. Hence, although chronic short sleep is associated with increased mortality risk, our results suggest that shortening of habitual sleep duration among older adults may not be a cause of concern. Our results also suggest that short or long sleepers who changed to recommended sleep duration at later life did not have a significant increased risk of mortality. Conversely, we observed an increased proportion of long sleepers with aging, as well as an increased risk of cardiovascular mortality when sleep duration lengthened to 9 hr or more.

The association between increased sleep duration and CVD mortality needs to be interpreted with caution as increased sleep duration among older adults could be a sign of poorer health outcomes or an epiphenomenon of comorbidity [23, 24]. Our findings generally support the recent sleep duration recommendations for older adults formulated by the American Academy of Sleep Medicine and Sleep Research Society [17] that are based on data mainly from Caucasian populations. The self-reported sleep duration in young adults in East Asia is between 1 and 2 hr less than their counterparts in Europe [25]. As such, our findings contribute to the literature on sleep epidemiology among Asians and provide an impetus for policy makers in this region to incorporate sleep education in plans for lifestyle risk-factor modification.

The strengths of our study include its large sample size, long duration of follow-up, and prospective longitudinal study design with information on sleep duration and other covariates collected at two time points, which allowed us to examine the relation between change in sleep duration and risk of mortality. In addition, we were also able to examine the different causes of death. Although we did not conduct any validation of the question on sleep duration, the duration of sleep assessed using this question has been examined with many other health outcomes in this cohort [23, 26–31]. Among its limitations, self-reported sleep duration likely represents time in bed rather than sleep time. We also did not distinguish between naps and nocturnal sleep. We also lacked information on sleep disorders, sleep quality [32], and social isolation [33], all of which might affect mortality. The sleep duration of the participants could have changed due to retirement, and we lacked data on such information. Nevertheless, since the retirement age in Singapore was between 55 and 60 years during the period of recruitment, as many as 50% of our participants were above 55 years old and could have retired at the time of recruitment. As this study only included participants who completed both baseline and follow-up II interviews, this could potentially introduce a selection bias. However, comparable results were obtained when we examined the association between baseline sleep duration and mortality in the entire cohort and in this smaller subcohort. Even though we adjusted for prevalent comorbidities in our statistical models, there could be misclassifications as these conditions were

self-reported, and there could still be residual confounding due to untracked medical conditions. Adjustment for the socioeconomic status of the participants using their highest level of education may also be incomplete.

In summary, keeping to a daily sleep duration of 7 hr is associated with lowest mortality risk and a change from any length of sleep to ≥ 9 hr in late adulthood should raise concerns about increased risk of mortality. The persistence of both extreme short (≤ 5 hr) and long (≥ 9 hr) sleep is also not desirable. Factors contributing to such extreme sleep durations or the lengthening of sleep duration remain topics for future experimental studies.

Supplementary Material

Supplementary material is available at *SLEEP* online.

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Notes

Conflict of interest statement. None declared.

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