Sleep Medicine 57 (2019) 128–134

Contents lists available at ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

Original Article

Association of daytime napping with incident cardiovascular disease in a community-based population

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ARTICLE INFO

Article history:
Received 5 November 2018
Received in revised form
14 February 2019
Accepted 19 February 2019
Available online 2 March 2019

Keywords:
Daytime napping
Cardiovascular disease
Community-based study
SHHS

ABSTRACT

Objective: To investigate the association between self-reported daytime napping habits and cardiovascular disease (CVD) in a large community-based study population.
Methods: Of the 4170 participants, 55.5% were women and the mean age was 63.1 years (SD, 11.0 years). CVD included cardiovascular death, congestive heart failure, myocardial infarction, stroke, angina, and revascularization and was defined as the first confirmed incidence of CVD during an average 11-year follow-up. Self-reported daytime napping habits were recorded using baseline questionnaires. Backward stepwise Cox regression analysis was used to explore the relationship between CVD and napping habits.
Results: In this study, 914 participants with CVD (21.9%) were observed. Participants who took regular long naps had a higher prevalence of incident CVD than did those who took regular short naps, irregular naps, or no naps (34.5% vs. 28.4%, 22.4%, 16.6%, respectively; $P < 0.001$). In the final backward stepwise Cox regression model, regular long naps were found to be associated with CVD (HR: 1.403, 95% CI: 1.079 −1.825, $P = 0.012$).
Conclusions: Regular long daytime napping was an independent risk factor for CVD. Healthy sleep habits may promote human health and prevent CVD.
Clinical trial registration: ClinicalTrials.gov Identifier: NCT00005275.

1. Introduction

Cardiovascular disease (CVD) has the highest morbidity and mortality rates worldwide [1]. Thus, the prevention and treatment of CVD have become a major public health concern. Previous studies have reported the association between habitual sleep and CVD [2,3]. Besides, daytime napping has also been found to be associated with diabetes mellitus, metabolic syndrome, and all-cause mortality [4–8]. However, there is ongoing controversy whether daytime napping is a risk factor for CVD. Yamada et al., showed that long daytime napping (≥60 min) is a risk factor for CVD [9]. Daytime napping was also found to increase the risk of CVD mortality, heart failure (HF), and cerebral infarction [10,11]. Nevertheless, a large cohort study with 16,374 participants demonstrated that there was no statistically significant associations between CVD and napping for over 1 h [7]. Additionally, a meta-analysis showed that daytime napping was not a predictor for CVD mortality [12]. These contrasting findings may be attributed to the different populations or classifications of daytime napping. Therefore, we conducted this study to investigate the association between daytime napping, in terms of frequency and duration, and CVD using the Sleep Heart Health Study (SHHS) database.

2. Methods

2.1. Study design

The SHHS was a community-based population study of the cardiovascular consequences of sleep-disordered breathing (Clinical Trials. gov identifier: NCT00005275). The study recruited participants from several prospective cohort studies in the United States between November 1, 1995 and January 31, 1998. CVD

Abbreviations: CVD, cardiovascular disease; HF, heart failure; CHF, congestive heart failure; SHHS, sleep Heart Health Study; PSG, polysomnography; AHI, apnea-hypopnea index; BMI, body mass index; CI, confidence interval; HR, hazard ratio; MI, myocardial infarction.

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https://doi.org/10.1016/j.sleep.2019.02.014
1389-9457/

outcomes were monitored and adjudicated by parent cohorts between baseline and 2011. The specific design and quality control procedures have been described previously (available at: http://www.jhsph.edu/shhs) [13]. Written consent for study participation was obtained from all participants after the institutional review boards of each participating field sites approved the study protocol. Access to SHHS database was obtained following an agreement with the Brigham and Women's Hospital. Exclusion criteria were (1) prevalent congestive heart failure, myocardial infarction, stroke, angina, or revascularization at study inception; and (2) missing data on about daytime napping and polysomnography (PSG) results and missing medical records. Finally, 4170 subjects were included in the current study.

2.2. Data collection

Demographic information including age, sex, body mass index (BMI), race, smoking status, education, marital status, apnea-hypopnea index (AHI), sleep duration, diabetes, hypertension, anthropometry, triglyceride levels, and total cholesterol levels were obtained at baseline examination. Self-reported napping habits were determined on the basis of responses to question such as "During a usual week, how many times do you nap for 5 min or more?" and "If you took any naps today, for how long did you sleep during the naps?". We defined the frequency categories for daytime napping as never, 1–4 times per week, 5–6 times per week, and daily. Daytime napping was divided into regular naps (≥5 times per week) and irregular naps (<5 times per week) [14]. Regular naps were further categorized as long naps (> 30 min) and short naps (≤30 min). AHI was calculated as all apneas and hypopneas per hour of sleep accompanied by at least a 4% drop in oxygen saturation [15].

2.3. Composite cardiovascular outcome

Survival time was calculated as the time from baseline PSG to the first occurrence of CVD during the follow-up period [16–23]. Composite CVD was defined as cardiovascular death, congestive heart failure (CHF), myocardial infarction (MI), stroke, angina, and revascularization.

2.4. Statistical analysis

We presented descriptive baseline characteristics according to CVD and non-CVD. Continuous variables were presented as Mean ± SD. Categorical variables were presented as frequencies with percentages. We used Student's t-test and the chi-square test to compare variables between two groups. Kaplan–Meier plots were used to evaluate the association between daytime napping and composite CVD outcome. Univariate and multivariable Cox regression analyses were used to explore the association between nap habit and CVD. Covariates exhibiting statistical significance upon age- and sex-adjusted analyses were entered into the backward stepwise Cox regression model. Hazard ratios (HR) and 95% confidence intervals (CIs) were reported. *P*-values <0.05 were considered statistically significant. Subgroup analyses stratified by age (≥60 years vs. <60 years), sex (men vs. women), diabetes (yes vs. no), hypertension (yes vs. no), smoking status (current vs.

Table 1
Baseline characteristics in all participants.

Characteristics	Total (n = 4170)	Incident CVD (n = 914)	No CVD (n = 3256)	*P* value
Age, years	63.1 ± 11.0	70.4 ± 9.5	61.0 ± 10.5	<0.001
Sex, n (%)				<0.001
Male	1854 (44.5)	487 (53.3)	1367 (42.0)	–
Female	2316 (55.5)	427 (46.7)	1889 (58.0)	–
Body mass index, n (%)				0.152
18–24.9	1099 (26.4)	220 (24.1)	879 (27.0)	–
25–29.9	1766 (42.4)	394 (43.1)	1372 (42.1)	–
≥30	1291 (31.0)	300 (32.8)	991 (30.4)	–
Race, n (%)				0.595
White	3644 (87.4)	794 (86.9)	2850 (87.5)	–
Other	526 (12.6)	120 (13.1)	406 (12.5)	–
Smoking status, n (%)				0.007
Current smoker	410 (9.8)	99 (10.8)	311 (9.6)	–
Former smoker	1778 (42.6)	422 (46.2)	1356 (41.6)	–
Never smoker	1976 (47.4)	391 (42.8)	1585 (48.7)	–
Education, n (%)				<0.001
≤15 years	2380 (57.1)	613 (67.1)	1767 (54.3)	–
>15 years	1422 (34.1)	262 (28.7)	1160 (35.6)	–
Marital Status, n (%)				0.004
Married	3303 (79.2)	698 (76.4)	2605 (80.0)	–
Other	802 (19.2)	207 (22.6)	595 (18.3)	–
AHI, n (%)				<0.001
<5	2104 (50.5)	376 (41.1)	1728 (53.0)	–
≥5	2066 (49.5)	538 (58.9)	1528 (46.9)	–
Sleep duration, n (%)				0.006
<6	380 (9.1)	98 (10.7)	282 (8.7)	–
6–8	2738 (65.7)	560 (61.3)	2178 (66.9)	–
>8	1052 (25.2)	256 (28.0)	796 (24.4)	–
Diabetes mellitus, n (%)	258 (6.2)	131 (14.3)	127 (3.9)	<0.001
Hypertension, n (%)	1483 (35.6)	496 (54.3)	987 (30.3)	<0.001
Hip circumference, cm	105.4 ± 10.3	105.0 ± 10.7	105.5 ± 10.2	0.293
Neck circumference, cm	37.6 ± 4.2	38.4 ± 4.0	37.3 ± 4.2	<0.001
Waist circumference, cm	97.2 ± 13.6	100.1 ± 13.3	96.4 ± 13.6	<0.001
Triglyceride, mg/dl	150.1 ± 101.0	153.7 ± 97.0	149.1 ± 102.1	0.240
Total cholesterol, mg/dl	206.9 ± 38.3	207.5 ± 38.5	206.7 ± 38.3	0.583
Follow-up time, years	10.9 ± 2.8	9.9 ± 3.1	11.2 ± 2.6	<0.001

AHI, apnea hypopnea index; CVD, cardiovascular disease. Results are presented as mean ± standard deviation or n (%).

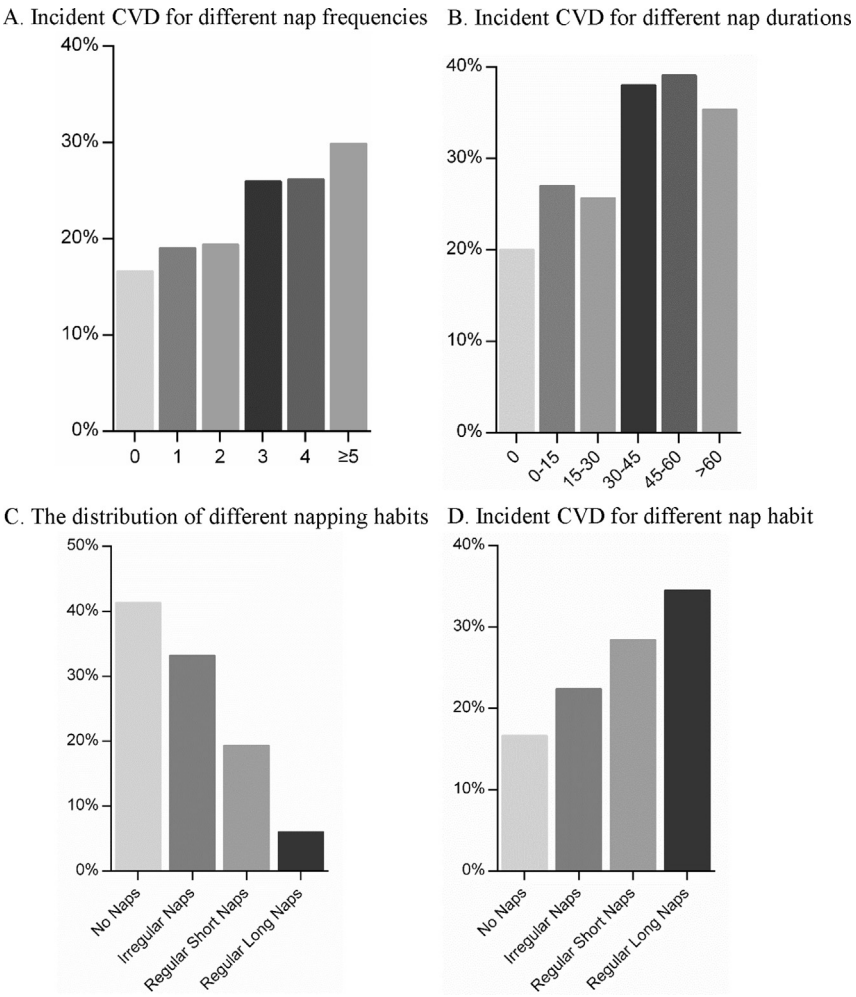

Fig. 1. Distribution of daytime napping habits. (A) Incident CVD for different nap frequencies; (B) Incident CVD for different nap durations; (C) The distribution of daytime napping habits in all participants; (D) Incident CVD for different nap patterns.

former vs. no), race (white vs. other), AHI (≥5 events/h vs. <5 events/h), marital status (married vs. other), education (>15 years vs. ≤15 years), BMI (18–24.9 kg/m^2 vs. 25–29.9 kg/m^2 vs. ≥30 kg/m^2), and sleep duration (<6 h vs. 6–8 h vs. >8 h) were also performed. All statistical analyses were conducted using SPSS, version 24.0 (SPSS Inc., Xi'an Jiaotong University, China).

3. Results

3.1. Participant' characteristics

Baseline characteristics of all participants with or without CVD are presented in Table 1. A total of 4170 participants (1854 men and 2316 women, 63.1 ± 11.0 years old) were included in this study. Individuals with CVD were more likely to be male, smokers, with less education, have hypertension, have diabetes mellitus, and have higher waist and neck circumference. In addition, the frequency of participants who took no naps, irregular naps, regular short naps, and regular long naps were 1725 (41.4%), 1384 (33.2%), 809 (19.4%), and 252 (6.0%), respectively (Fig. 1C).

3.2. Association between daytime napping status and CVD

During the mean 11-year follow-up, 914 participants (18.4%) experienced cardiovascular disease. Participants with a higher nap frequency ($P < 0.001$) or longer nap duration ($P < 0.001$) had a higher incidence of CVD (Fig. 1A and B). Moreover, the incidence of CVD in participants who took regular long naps was significantly higher than that in those who took regular short naps, irregular naps, or no naps (34.5% vs. 28.4%, 22.4%, 16.6%; $P < 0.001$) (Fig. 1D).

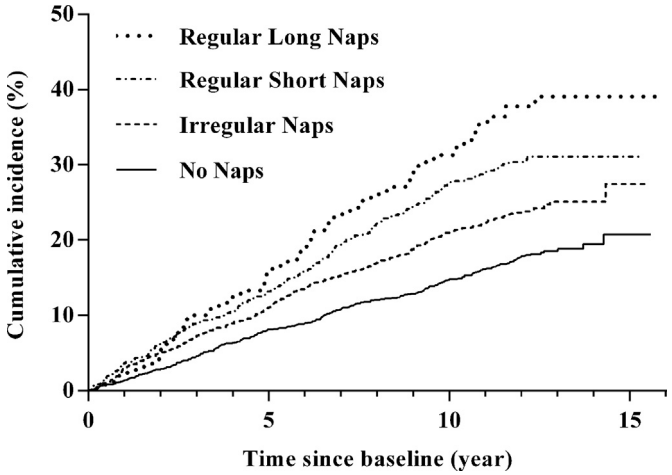

Fig. 2. Kaplan–Meier survival curves for CVD risk stratified by daytime napping categories (regular long naps, regular short naps, irregular naps, and no naps).

Kaplan–Meier analysis showed an increased incidence of CVD among participants who took in regular long naps (Fig. 2).

Regular long naps (HR: 2.368, 95% CI: 1.863–3.010, $P < 0.001$), regular short naps (HR: 1.875, 95% CI: 1.576–2.230, $P < 0.001$), and irregular naps (HR: 1.413, 95% CI: 1.203–1.659, $P < 0.001$) were found to be associated with CVD in univariate Cox regression model. Before further multivariate regression analysis, the relationship between AHI, a potential cofounding factor and CVD was also evaluated. However, AHI was not associated with CVD after adjustment for age and sex (HR: 1.134, 95%CI: 0.989–1.3). Therefore, only daytime napping, age, sex, race, education, marital status, smoking status, diabetes mellitus, hypertension, sleep duration, neck circumference, waist circumference, and triglyceride levels were included in the final backward stepwise Cox regression model. It showed that regular long naps were associated with an increased risk of CVD (HR: 1.403, 95%CI: 1.079–1.825, $P = 0.012$) (Table 2).

3.3. Subgroup analyses

Additionally, we performed subgroup analyses by stratifying participants according to AHI (<5 event/h vs. ≥5 event/h) and hypertension (yes vs. no) in order to further investigated the association between daytime napping and CVD (Table 3). When stratified by AHI and hypertension, no significant interaction was observed. Subgroup analyses stratified by age (≥60 years vs. <60 years), sex (male vs. female), race (white vs. other), marital status (married vs. other), education (>15 years vs. ≤15 years), diabetes (yes vs. no), sleep duration (<6 h vs. 6–8 h vs. >8 h), smoking status (current and former vs. no) were also performed. Significant interactions were not found in these analyses (data not shown).

4. Discussion

We evaluated the relationship between habitual daytime napping and incident CVD in a community-based population. In our study, CVD was a composite endpoint including cardiovascular death, CHF, MI, stroke, angina, and revascularization. Furthermore, we used a combination of the frequency and duration of daytime napping to categorize the different nap patterns. After adjusting for age, sex, race, education, marital status, smoking status, diabetes mellitus, hypertension, sleep duration, neck circumference, waist circumference, and triglyceride levels, we found that people with

Table 2
HRs and 95% CIs for daytime napping associated with cardiovascular disease.

All subjects	Univariate Models	*P*	Sex and age adjusted	*P*	Multivariable adjusted[a]	*P*
	HR (95%CI)		HR (95%CI)		HR (95%CI)	
Daytime napping						
Regular Long Naps	2.368 (1.863–3.010)	<0.001*	1.525 (1.195–1.946)	0.001*	1.403 (1.079–1.825)	0.012*
Regular Short Naps	1.875 (1.576–2.230)	<0.001*	1.304 (1.092–1.556)	0.003*	1.147 (0.949–1.386)	0.155
Irregular Naps	1.413 (1.203–1.659)	<0.001*	1.220 (1.038–1.434)	0.016*	1.133 (0.951–1.349)	0.161
No Naps	1		1		1	
Age						
≥60	4.573 (3.812–5.487)	<0.001*			3.371 (2.709–4.196)	<0.001*
<60	1				1	
Sex						
Male	1.537 (1.350–1.751)	<0.001*			1.560 (1.341–1.816)	<0.001*
Female	1				1	
Body mass index						
≥30	1.166 (0.980–1.387)	0.084	1.087 (0.913–1.294)	0.350		
25–29.9	1.114 (0.944–1.314)	0.201	1.003 (0.850–1.185)	0.967		
18–24.9	1		1			
Race						
White	0.938 (0.774–1.137)	0.513	0.728 (0.600–0.883)	0.001*	0.792 (0.622–1.007)	0.057
Other	1		1		1	
Education						
≤15 years	1.507 (1.304–1.742)	<0.001*	1.380 (1.192–1.598)	<0.001*	1.250 (1.071–1.459)	0.005*
>15 years	1		1		1	
Marital Status						
Married	0.773 (0.662–0.902)	0.001*	0.704 (0.600–0.826)	<0.001*	0.758 (0.636–0.902)	0.002*
Other	1		1		1	
Smoking status						
Current smoker	1.269 (1.018–1.582)	0.034*	1.453 (1.164–1.814)	0.001*	1.339 (1.042–1.721)	0.022*
Former smoker	1.259 (1.098–1.445)	0.001*	1.116 (0.968–1.287)	0.130	1.101 (0.946–1.282)	0.213
Never smoker	1		1		1	
Diabetes mellitus	3.348 (2.781–4.031)	<0.001*	2.551 (2.116–3.074)	<0.001*	1.975 (1.614–2.416)	<0.001*
Hypertension	2.482 (2.179–2.828)	<0.001*	1.986 (1.740–2.267)	<0.001*	1.806 (1.562–2.088)	<0.001*
AHI						
≥5	1.560 (1.367–1.780)	<0.001*	1.134 (0.989–1.300)	0.072		
<5.0	1		1			
Sleep duration						
> 8	1.234 (1.064–1.431)	0.005*	1.237 (1.067–1.435)	0.005*	1.234 (1.051–1.449)	0.010*
<6	1.313 (1.059–1.627)	0.013*	1.171 (0.944–1.451)	0.151	1.069 (0.851–1.343)	0.564
6–8	1		1		1	
Hip circumference, cm	0.996 (0.990–1.003)	0.288	1.002 (0.995–1.009)	0.631		
Neck circumference, cm	1.059 (1.044–1.075)	<0.001*	1.034 (1.013–1.056)	0.001*		
Waist circumference, cm	1.018 (1.013–1.023)	<0.001*	1.011 (1.006–1.017)	<0.001*	1.006 (1.001–1.012)	0.022*
Triglyceride	1.000 (1.000–1.001)	0.157	1.001 (1.000–1.001)	0.025*		
Total cholesterol	1.000 (0.999–1.002)	0.705	1.000 (0.998–1.002)	0.916		

AHI, apnea hypopnea index; 95% CI, 95% confidence interval; HR, hazard ratio.
* $P < 0.05$.
[a] Adjusted for the covariates that were statistically significant on age- and sex-adjusted analysis (age, sex, daytime napping, race, education, marital status, smoking status, diabetes mellitus, hypertension, sleep duration, neck circumference, waist circumference, triglyceride).

Table 3
Multivariate Cox regression analysis for CVD stratified by AHI and Hypertension.

	Univariate Models	*P*	Sex and age adjusted	*P*	Multivariable adjusted	*P*
	HR (95%CI)		HR (95%CI)		HR (95%CI)	
Hypertension						
Daytime napping						
Regular Long Naps	1.620 (1.171–2.241)	0.004*	1.201 (0.864–1.669)	0.276		
Regular Short Naps	1.586 (1.252–2.008)	<0.001*	1.241 (0.977–1.576)	0.077		
Irregular Naps	1.277 (1.022–1.594)	0.031*	1.103 (0.882–1.379)	0.390		
No Naps	1		1			
Non-hypertension[a]						
Daytime napping						
Regular Long Naps	2.756 (1.928–3.941)	<0.001*	1.722 (1.198–2.477)	0.003*	1.627 (1.114–2.375)	0.012*
Regular Short Naps	1.841 (1.423–2.382)	<0.001*	1.230 (0.945–1.602)	0.124	1.071 (0.810–1.416)	0.630
Irregular Naps	1.380 (1.093–1.743)	0.007*	1.221 (0.966–1.543)	0.095	1.205 (0.941–1.542)	0.140
No Naps	1		1		1	
	*P*interaction = 0.197					
AHI ≥ 5[b]						
Daytime napping						
Regular Long Naps	2.205 (1.627–2.990)	<0.001*	1.692 (1.244–2.302)	0.001*	1.581 (1.148–2.177)	0.005*
Regular Short Naps	1.809 (1.445–2.264)	<0.001*	1.408 (1.122–1.768)	0.003*	1.300 (1.027–1.647)	0.029*
Irregular Naps	1.299 (1.042–1.618)	0.020*	1.233 (0.989–1.537)	0.063	1.177 (0.936–1.482)	0.164
No Naps	1		1		1	
AHI<5						
Daytime napping						
Regular Long Naps	2.261 (1.516–3.372)	<0.001*	1.286 (0.856–1.931)	0.225		
Regular Short Naps	1.640 (1.231–2.185)	0.001*	1.119 (0.836–1.498)	0.451		
Irregular Naps	1.470 (1.161–1.860)	0.001*	1.196 (0.943–1.518)	0.140		
No Naps	1		1			
	*P*interaction = 0.657					

AHI, apnea hypopnea index; CVD, cardiovascular disease; 95% CI, 95% confidence interval; HR, hazard ratio.
* $P < 0.05$.
[a] Subgroup of non-hypertension: Daytime napping, age, sex, education, marital status, smoking status, diabetes mellitus, sleep duration, neck circumference, and waist circumference were entered in the backward stepwise cox regression model.
[b] Subgroup of AHI ≥ 5: Daytime napping, age, sex, race, education, marital status, smoking status, diabetes mellitus, hypertension, sleep duration, and waist circumference were entered in the backward stepwise cox regression model.

regularly long naps during the daytime had an incidence of CVD almost 1.4 times higher than those who took no naps.

A large number of studies have demonstrated a relationship between sleep duration and human health. Too long or too short sleep duration is associated with obesity, diabetes mellitus, hypertension, incident CVD, and all-cause mortality [2,3,24–27]. A recent cohort study with 116,632 people from 21 countries showed a J-shaped association between total daily sleep duration and all-cause mortality and cardiovascular events. Total sleep duration of 6–8 h per day had the lowest risk of deaths and major cardiovascular events [28]. Daytime napping is a short period of sleep during daytime which is considered as an adjunct to the usual nocturnal sleep period. Many studies have focused on the relationship between self-reported daytime napping and CVD, but there are still conflicting evidences on whether napping is a risk factor for CVD [7,9–12,14,29]. Through a meta-analysis, Yamada et al., showed that daytime naps which lasted for more than 60 min were a risk factor for CVD [9]. Naps were also found to be a risk factor for MI, cerebral infarction, HF, and CVD mortality [10,11,14,29]. However, a large cohort study with 23,620 middle-aged participants found that self-reported daytime sleep was not associated with MI or stroke in both non-hypertensive and hypertensive participants [8]. Liu et al., conducted a meta-analysis and demonstrated that daytime napping was not associated with CVD mortality [12]. Several studies also supported that daytime napping was not a risk factor for CVD [7].

Our study indicated that regularly long napping during the daytime is a risk factor for CVD. Such findings are similar to but not identical to some of the previous studies which approved this standpoint. The difference may attribute to the different study designs, nap categorization or populations. Previous studies have usually investigated daytime napping habits using baseline questionnaires including questions such as “Do you take a daytime nap?” or “Do you sleep during the day?” [10,30], which only comparing nappers with non-nappers. Our baseline questions included “During a usual week, how many times do you nap for 5 min or more?” and “If you took any naps today, for how long did you sleep during the naps?”. We divided daytime napping into four categories based on a combination of nap frequency and duration. Furthermore, previous nap duration was usually divided into less than 1 h [7,9,12,14], but we found that nap duration more than 30 min obviously increased the incidence of CVD, which had more reference value for people. Moreover, more nap frequency tended to associate a higher prevalence of CVD especially in participants with more than five naps per week. Therefore, our results indicated that participants with more than five naps per week and more than 30 min nap duration had a high risk of CVD.

AHI is the average number of episodes of apnea and/or hypopnea per hour of sleep and a well-known cardiovascular risk factor [15]. It was related with CVD in the univariate model of our study (HR: 1.56, 95%CI: 1.367–1.780). However, after adjustment for age and sex, the association was imprecise (HR: 1.134, 95%CI: 0.989–1.3). Moreover, interaction analysis also revealed AHI (<5 or ≥5) had no significant interaction ($P_{interaction} = 0.657$) on the relationship between napping and CVD. It suggested that sleep apnea may not contribute to significant confounding effect in the current study.

The mechanism of the relationship between daytime napping and CVD is still unknown. Some sleep-related biological mechanisms may explain the association between daytime napping and incident CVD. Sleep apnea, poor sleep quality, and short sleep duration were associated with both daytime napping and CVD [22].

In addition, several meta-analyses suggested that long napping time was associated with an increased risk of type 2 diabetes and hypertension [31–34]. Diabetes and hypertension are known to be the main risk factors for cardiovascular disease [35,36]. Further, blood pressure and heart rate fluctuations in the morning or upon awakening from daytime napping, caused by the activation of the sympathetic nervous system, were closely related to an increased risk of CVD [37,38].

There are several strengths to this study. First, because this was a community-based population study, our findings are generalizable. Second, our daytime napping categories considered both nap duration and nap frequency. Yet, our research also has some limitations. Measurement errors and recall bias were unavoidable because self-reported questionnaires were used to investigate daytime napping habits and sleep duration, which may show major discrepancies compared to objective findings. The SHHS database didn't contain the information of employment status or shift work. Thus, these confounders have not been adjusted in the regression models. In addition, the majority of participants were white and older than 60 years. Therefore, our results should not be extended to all ethnic groups and younger subjects.

5. Conclusion

Regular long daytime napping is associated with an increased risk for CVD. Therefore, napping habits may be a useful marker for incident CVD. For the purpose of CVD prevention, future studies should explore effective nap habit interventions.

Funding

The study was supported by the National Natural Science Foundation of China (81770057).

Acknowledgements

We appreciate the Brigham and Women's Hospital for sharing the Datasets of Sleep Heart Health Study (SHHS). In addition, SHHS acknowledges the Atherosclerosis Risk in Communities Study; the Cardiovascular Health Study; the Framingham Offspring and Omni Study; the Strong Heart Study; Tucson Epidemiological Study of Obstructive Lung Disease; the cohort studies of respiratory disease in Tucson; and cohort studies of hypertension in New York. SHHS is particularly grateful to the members of these cohorts who agreed to participate in SHHS as well. SHHS further recognizes all of the investigators and staff who have contributed to its success. A list of SHHS investigators, staff and their participating institutions is available on the SHHS website, www.jhucct.com/shhs.

Conflict of interest

The authors report no conflict of interest.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2019.02.014.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2019.02.014.

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