Original Article

Associations of Daytime Napping with Incident Cardiovascular Diseases and Hypertension in Chinese Adults: A Nationwide Cohort Study*

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Abstract

Objective This study aimed to examine the associations of daytime napping with incident risks of cardiovascular diseases (CVDs) and hypertension (HTN).

Methods Data for napping and CVD outcomes in 25 provinces were collected from baseline (2010) and three waves of follow-up (2012–2017) investigations of the China Family Panel Studies. Cox frailty models with random intercepts for the surveyed provinces were used to assess the longitudinal effects of daytime napping on CVD and HTN.

Results Compared with non-nappers, 30+ min nappers had higher risks of CVD and HTN, while no significant associations were observed among < 30 min nappers. Incident risks among 30- to < 60-min nappers increased by 22% [hazard ratio (HR) 1.22, 95% confidence interval (*CI*) 1.08–1.39] for CVD and 21% (1.21, 1.04–1.41) for HTN, respectively, with corresponding HRs of CVD and HTN of 1.27 (1.09–1.47) and 1.38 (1.16–1.65) among ≥ 60 min nappers. Nap-associated CVD risks varied by subgroups, with stronger associations in participants with lower body mass index (< 24 kg/m^2), physically inactive persons, smokers, and participants with longer nighttime sleep (≥ 7 h/night). Significant effects of daytime napping were observed on rural and northern residents only, highlighting great regional variations in CVD risks associated with napping habits.

Conclusions This cohort study revealed strong evidence that long daytime napping (≥ 30 min) is associated with an increased incidence of cardiovascular events.

Key words: Daytime napping; Cardiovascular disease; Hypertension; Adults; Sleep duration

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INTRODUCTION

Cardiovascular diseases (CVDs) are the top leading cause of global mortality and have been regarded as one of the greatest threats to human health[1]. Evidence suggested the continuing rise in the annual number of CVD cases in China[2]. As it affects 31.1% of the adult population worldwide[3], hypertension (HTN) has become an important public health challenge in China in the past decades[4].

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Previous epidemiologic studies have identified tobacco use, sodium intake, and physical inactivity as major behavioral contributors to CVD[5] and HTN[6]; other factors remain insufficiently explored. Recently, emerging evidence[7-9] has revealed that sleep is possibly associated with the development of CVD and HTN, but the contribution of daytime napping has not been fully investigated in epidemiologic studies.

Daytime napping, or siesta, is considered a common practice and a healthy habit[10]. A previous study demonstrated that the prevalence of regular napping (at least once a week) varied from 30% to 70% in many countries within South America, the Middle East, and Southeast Asia[11]. In China, the prevalence of habitual napping usually increases with age, corresponding to 61.7% and 46.8% in men and women aged 60 years or older[12]. Although most people consider taking naps a beneficial strategy in fighting fatigue, the effects of different patterns of napping (e.g., frequency and duration) on human health are less known.

Recent studies have demonstrated associations between daytime napping and a series of adverse health outcomes, including diabetes mellitus[13], metabolic syndrome[14], breast cancer[15], and all-cause mortality[16]. In terms of CVDs, there is an ongoing controversy regarding whether daytime napping is a risk factor for CVDs abroad and at home. Specifically, nap-CVD associations were reported in some developed countries, such as Japan[17], the United States[18], Israel[19], and Germany[20]. However, several studies have revealed the protective effects of siestas on CVDs[21,22] or null associations of napping with CVD[23-25]. In China, several investigations have linked nap with an elevated risk of CVDs by enrolling a regional cohort (e.g., Dongfeng-Tongji cohort)[12,26] or cross-sectional samples from local areas[27]; however, a community-based study in an older rural population[28] identified no significant associations of HTN with daytime napping. Notably, no nationwide cohort evidence is available to date from a representative Chinese population. In this study prospective cohort study in a national Chinese survey sample, we aimed to evaluate the association of CVDs with daytime napping and provide scientific evidence into future effective interventions designed to reduce CVD incidences.

METHODS

Study Design and Population

The data were derived from China Family Panel Studies (CFPS), a representative and comprehensive ongoing nationwide longitudinal social survey of Chinese communities, families, and individuals launched by the Peking University Institute of Social Science Survey in 2010[29]. In this survey, the samples at baseline were enrolled from 162 county-level units from 25 provinces and municipalities, accounting for 94.5% of the national population (Figure 1). The CFPS survey was conducted on average every 2 years and has released the baseline dataset in 2010 and four waves of follow-up data (CFPS 2012, 2014, 2016, and 2018); however, the CFPS 2018 was not fully publicly accessed at the time of our study. Baseline questionnaire survey interviewed 14,960 households and 42,590 individuals, with successful tracking rates of 85%, 89%, and 89% in 2012, 2014, and 2016 follow-ups, respectively. Trained investigators performed face-to-face interviews aided by computer-assisted personal interviewing technology.

All participants signed informed consent forms. The investigation was ethically approved by the Peking University Biomedical Ethics Review Committee (Approval No. IRB00001052-14010). Additional details on sampling and design could be found in prior publications[30] and are available at the Peking University Open Research Data Platform (https://opendata.pku.edu.cn/dataverse/CFPS/).

Data Extraction and Cohort Design

In this study, we used four waves of CFPS adult datasets (2010, 2012, 2014, and 2016). A total of 33,600 participants (age 16–105 years) completed the baseline questionnaire in 2010. The following exclusion criteria were applied to conceive a cohort design investigating nap-CVD associations in Chinese adults: (1) missing CVD information at baseline (n = 2,356), (2) self-reported chronic diseases at baseline (n = 4,939), (3) loss to follow-up (n = 9,765), (4) age < 30 years (n = 2,361), and (5) missing on napping information and covariates (n = 473). Finally, a cohort of 13,706 participants from 2010 to 2017 was included in our study (Figure 2).

Assessment of Daytime Napping and Nighttime Sleep

Self-reported napping habits and nap duration were ascertained based on these questions: “Do you have the habit of taking afternoon naps?” “If yes, how long a nap do you usually take?” Daytime napping was classified into four categories: 0 min (no napping), < 30 min, 30 to 60 min, and ≥ 60 min. Based on a scientific clinical trial that recommended a minimum nap time of 30 min/day for human health[31]

and previous similar studies on the classification of napping duration[12], we regarded napping < 30 min and ≥ 30 min as short and long naps, respectively. The nocturnal sleep duration was also calculated by subtracting previously obtained nap duration from the total daily sleep time in the questionnaire. Nighttime sleep duration was categorized into three groups: < 6 h, 6–8 h, and ≥ 8 h[32].

Outcomes

The occurrence of CVDs was determined by asking the following question: "During the past 6 months, have you had any doctor-diagnosed chronic diseases?" The respondents have CVD if they answered "yes" to the above question and could list two major chronic diseases. According to the Disease Classification Codebook and Text Coding Technical Report for Chinese Family Panel Studies, we defined three cardiovascular events as health outcomes of interest for the analysis: (1) total CVD, including but not limited to HTN and stroke, (2) HTN, and (3) stroke. We did not include other subtypes of CVD for analysis because these incident cases were rare during the follow-up periods. We redefined the date of diagnosis as the intermediate time point between the last interview date and the next visit date during the predefined follow-up period. Previous studies have reported the validity of self-reported and physician-diagnosed chronic diseases[33]. Person-years of follow-up were calculated as the interval from the dates of baseline interviews (2010 or 2011) to the dates of the final follow-up interviews (2016 or 2017) or the occurrence of a CVD event.

Covariates

Standardized questionnaires were used to obtain information about demographic and socioeconomic factors and lifestyle behaviors. Demographic and socioeconomic status included gender (male and female), age (30–44, 45–59, and ≥ 60 years), body mass index (BMI) (underweight, < 18.5 kg/m^2; normal, 18.5–23.9 kg/m^2; overweight, 24–27.9 kg/m^2; obese, ≥ 28 kg/m^2), ethnicity (Han and minority), marital status (married, widowed, and single), residential region (urban and rural areas), geolocation (north and south), educational attainment (illiterate, 1–6, 7–12, and > 12 years), employment status (current, former, and never), and annual household income (RMB) (low, 0–15,000; medium, 15,000–40,000; high, ≥ 40,000). Behavioral

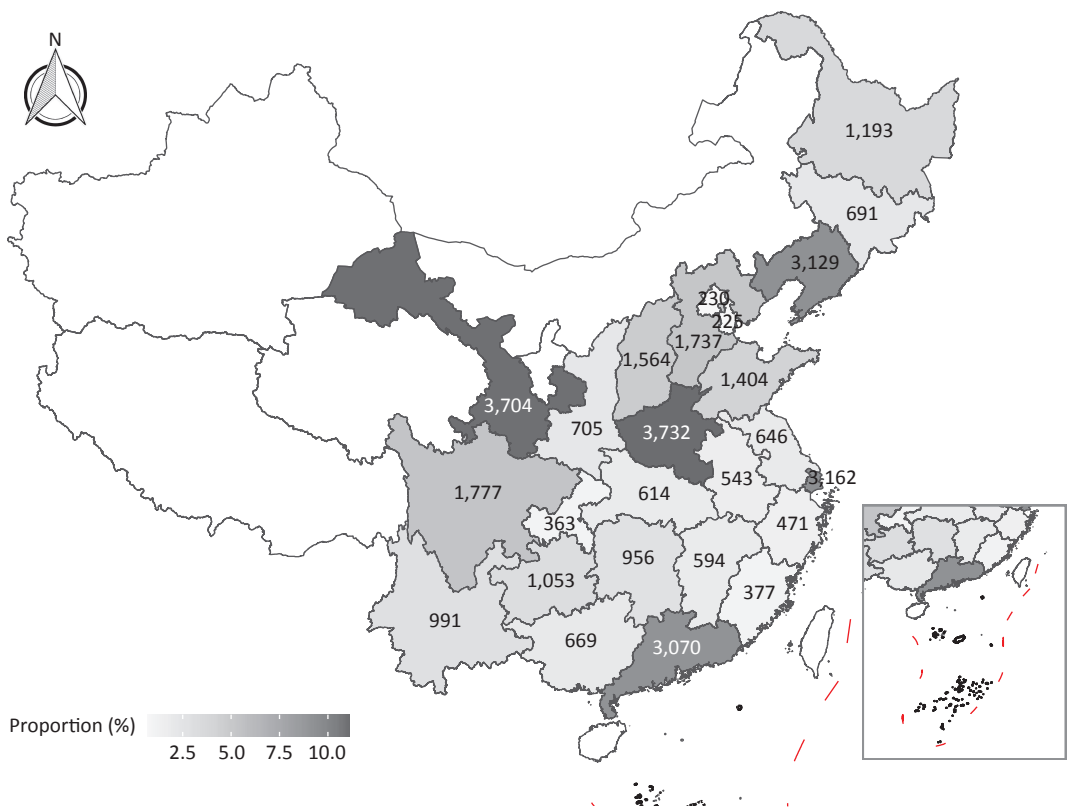

Figure 1. Distribution of adult samples at baseline.

factors also were assessed, including physical activity (0, 1–150, and > 150 min/week), smoking status (yes and no), and alcohol consumption (yes and no). Specifically, BMI was calculated by dividing weight in kilograms by the square of height in meters and grouped according to the guidelines for prevention and control of overweight and obesity in Chinese adults[34]. The northern and southern regions were divided according to China's geographical boundaries, namely, the Qinling Mountains and Huai River. Moderate physical exercise was defined as at least 1–150 min/week of physical activity based on 2020 WHO physical activity guidelines[35] and Chinese Dietary Guideline (2021) (http://dg.cnsoc.org/). Smoking and drinking status were assessed with the question: "Have you used at least one cigarette/drink alcohol during the recent month? " and "Have you ever smoked/drunk alcohol?"[36,37].

Statistical Analyses

Baseline characteristics of the participants were described using mean ± SD (standard deviation) for continuous variables (e.g., age and BMI) and percentages for categorical covariates (e.g., gender, ethnicity, and educational attainment) among nappers (< 30, 30–60, and ≥ 60 min) versus non-nappers. Cox frailty models with random intercepts for surveyed provinces were applied to calculate the adjusted hazard ratios (HRs) and to account for clustering within provinces[38]. A previous epidemiologic study applied Cox frailty models to explore the effects of sleep on mortality and morbidity outcomes[11]. The global test for proportional hazards assumption in the adjusted Cox model was verified by evaluating the weighted Schoenfeld residuals, and we detected no violations with all P values > 0.05[39]. In our nap-CVD analyses, we used (1) age- and gender-adjusted model and (2) multivariate models adjusting for gender, age, BMI, ethnicity, marital status, residential region, educational attainment, employment status, annual household income, physical activity, smoking status, alcohol consumption, and sleep duration.

We also conducted subgroup analyses by gender (male versus female), age (< 50 versus ≥ 50 years), BMI (< 24 versus ≥ 24 kg/m^2), residential region (urban versus rural area), geolocation (north versus south), physical activity (no versus yes), smoking status (no versus yes), alcohol consumption (no versus yes), and sleep duration (< 7 versus ≥ 7 h/night). The BMI cut-off value of 24 kg/m^2 was in line with the Chinese adults' standard of WS/T 428–2013 proposed by the Working Group on Obesity[40]. The joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society suggested an optimal sleep duration of 7 h per day[41], and we defined short and long sleep duration using 7 h/night as a cut-off point. P for trend was calculated to examine the linear trend between CVDs and nap duration in the overall and subgroup analyses.

Several sensitivity analyses were performed to check the robustness of the main findings by changing regression modeling choices. To address the potential reverse causation that relatively unhealthy individuals may disturb nap patterns, first, lagged analysis was conducted by excluding individuals who developed the interested outcomes 1 year after the baseline survey[9]. Second, given that napping is more prevalent in older adults than in younger ones, the analysis was restricted to participants aged < 75 years[42]. Sensitivity analysis was also performed by excluding those who had changed nap behaviors during follow-ups to eliminate the potential influence of temporal changes in daytime-napping behaviors. All nap-CVD associations were reported using HRs and corresponding 95% confidence intervals (*CI*s). A two-sided P value < 0.05 was considered significant. All statistical analyses were implemented by R software (version 3.6.2, R Foundation for Statistical Computing, Vienna, Austria), using the package "coxme" for Cox frailty modeling.

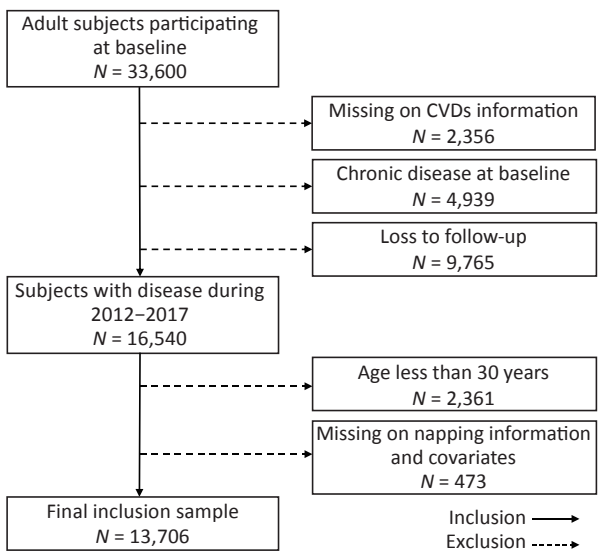

Figure 2. Inclusion process of our nap-CVD cohort study from CFPS adult datasets 2010–2017.

RESULTS

Sample Characteristics

Table 1 describes the baseline characteristics of the adults stratified by napping duration. A total of 13,706 participants (6,676 men and 7,030 women, 49.5 ± 11.3 years old) were involved, with 1,526 CVD, 1,098 HTN, and 413 stroke incidents during the 97,415.82 person-years of follow-up (median follow-up, 6.1 years). The proportions of the population with napping duration of < 30, 30 to 60, and ≥ 60 min were 9.4%, 24.7%, and 15.6%, respectively. More than half of the participants lived in rural communities (56.8%) and were from the northern regions (59.2%). The participants had an average of 6.7 years of academic education, wherein > 20% were illiterate. Approximately 75.6% of adults responded "no" to participating in any physical activity, and over three-fifths were never-smokers (60.9%) and never-drinkers (77.2%). As regards nighttime sleep, participants who reported a sleep duration of < 6 h and ≥ 8 h per night accounted for 18.5% and 25.4%, respectively.

Overall Napping-CVD Association

Table 2 outlines the crude and adjusted HRs for the associations between daytime napping and CVD and HTN. Compared with non-nappers, both crude and multivariate models revealed higher risks of incident CVD and HTN in nappers ≥ 30 min and a greater risk of stroke in medium nappers (30–60 min), while no significant associations were found in short nappers (0–30 min). The trend analysis of nap-CVD associations demonstrated significantly elevated incident risks with napping duration. For instance, incident risks increased respectively by 22% (1.22, 1.08–1.39) for CVD and 21% (1.21, 1.04–1.41) for HTN in 30 to < 60 min nappers, with corresponding HRs of 1.27 (1.09–1.47) and 1.38 (1.16–1.65) among nappers ≥ 60 min.

Subgroup Analyses

Table 3 and Table 4 summarize subgroup-specific estimates for associations of CVD and HTN risks with daytime napping. Overall, evident nap-incidence associations were consistently observed in 30+ min nappers, while nap-associated risks tended to be more profound among nappers with > 1 h/day. Significant trends for greater risks of CVD and HTN associated with longer naps were observed in all strata except for urban dwellers, south, and active physical exercise (P_{trend} > 0.05). Stratified analyses for stroke incidence are presented in Supplementary Table S1 (available in www.besjournal.com), where in associations with medium midday napping existed in female, older participants, underweight adults (BMI < 24 kg/m^2), rural and north residents, smokers, non-drinkers, and long sleepers.

In gender-specific associations, both men and women exhibited increased risks with longer napping duration (P_{trend} < 0.02). Generally, larger risks were identified in adults aged 30–49 years, particularly for HTN, with a p value for interaction of 0.092. Higher nap-associated risks mainly existed in participants with lower BMI (< 24 kg/m^2), except for HTN in 60+ min nappers. We found some evidence of regional differences in nap-CVD associations, where increased risks occurred in rural and northern residents only. Specifically, significant effect modification by geolocation (north China versus south China) was identified for total CVD (P = 0.043) and HTN (P = 0.027).

Our results also highlighted that the nap-CVD association was modified by physical activity, with larger incident risks found among physically inactive adults. Smokers and alcohol drinkers were observed to have higher CVD risks induced by longer napping. Specifically, the incidence of CVD and HTN remarkably increased among smokers with 30+ min naps, while risks elevated significantly only in drinkers who napped ≥ 60 min. Moreover, associations of long napping duration with CVDs appear to be more evident among adults who had longer nocturnal sleep. For instance, 30–60 min of napping resulted in 30% (9%–55%) and 31% (6%–62%) higher risks of CVD and HTN in adults who slept ≥ 7 h/night, respectively, corresponding to insignificant HRs of 1.17 (0.96–1.42) and 1.13 (0.90–1.43) in those slept < 7 h/night.

Sensitivity analyses (Supplementary Table S2 available in www.besjournal.com) demonstrated the robustness of our main findings that nap ≥ 30 min was associated with an increased risk of CVD events. In terms of total CVD outcome in relation to napping duration of 30 to < 60 min, the risk estimates kept unchanged when we excluded CVD cases diagnosed in the initial first year after the baseline study or excluded those aged > 75 years, with HRs ranging from 1.22 (1.08, 1.39) to 1.23 (1.09, 1.40) (model 1) and 1.25 (1.10, 1.42) (model 2), respectively. The estimated HRs slightly increased when restricting our analysis to participants without changes in daytime-napping behaviors, while our main findings remained [HR = 1.38 (1.20, 1.57), model 3].

Table 1. Baseline characteristics of included participants (*n* = 13,706) by daytime napping

Items	Total	Nap duration			
		0 min	< 30 min	30 to 60 min	≥ 60 min
Population					
Persons, *n*	13,706	6,884	1,292	3,383	2,147
Incident CVD, *n*	1,526	665	147	428	286
Incident HTN, *n*	1,098	474	97	307	220
Incident stroke, *n*	413	183	31	132	67
Individual covariates					
Male, %	48.7	47.7	43.0	50.1	53.1
Age, years	49.5 ± 11.3	49.0 ± 11.3	48.4 ± 11.1	49.9 ± 11.3	50.1 ± 11.5
BMI, kg/m^2	22.9 ± 3.3	22.4 ± 3.2	23.0 ± 3.3	22.9 ± 3.3	23.1 ± 3.3
Han ethnicity, %	93.5	91.3	95.6	95.3	95.9
Married, %	93.3	92.8	93.0	93.7	92.9
Urban, %	43.2	43.1	51.1	44.5	36.4
North, %	59.2	51.2	63.5	65.0	73.5
Educational attainment, %					
Illiteracy	22.4	25.4	15.8	19.0	21.8
1–6 years	26.3	26.2	22.1	26.3	29.0
7–12 years	46.1	44.6	52.6	48.2	46.4
> 12 years	5.2	3.8	9.5	6.5	2.7
Employment status, %					
Current	55.3	55.0	59.8	53.7	56.1
Former	28.6	27.8	27.3	30.9	28.3
Never	16.1	17.2	12.8	15.5	15.6
Annual household income, %					
Low	28.8	30.6	23.8	27.1	28.9
Medium	43.4	42.1	45.0	43.6	46.0
High	27.8	27.3	31.2	29.4	25.1
Physical activity, %					
0 min/week	75.6	80.2	64.2	70.9	75.1
1–150 min/week	23.9	19.4	34.9	28.6	24.1
> 150 min/week	0.5	0.4	0.9	0.5	0.8
Smoking status, %					
Yes	39.0	38.1	33.9	39.5	44.8
No	60.9	61.9	66.1	60.5	55.2
Alcohol consumption, %					
Yes	22.8	21.3	21.5	23.4	27.4
No	77.2	78.7	78.6	76.6	72.7
Sleep duration, %					
< 6 hours/night	18.5	12.0	12.9	20.0	40.0
6 to 8 hours/night	56.1	57.3	59.2	59.4	45.0
≥ 8 hours/night	25.4	30.8	27.9	20.6	15.0

Note. Data are presented using mean ± SD for continuous variables and percentages for categorical variables. BMI, body mass index; CVD, cardiovascular disease; HTN, hypertension.

DISCUSSION

To the best of our knowledge, this is the first nationwide population-based cohort study assessing the effects of daytime napping on major CVDs and HTN in China. In this study, we found that a napping duration of ≥ 30 min per day was associated with higher risks of CVD and HTN, while no significant associations were observed among those who napped for 0–30 min.

Nap-CVD Associations

Existing epidemiologic evidence was generally inconsistent worldwide regarding the effects of daytime napping on CVD[16,43]. A few previous studies have demonstrated that midday napping was not associated with CVD events[24,25], while a recent Greek[22] and Swiss[21] prospective cohort study revealed that daytime napping may play as a protective factor in the development of incident CVD. In our study, a long napping duration (≥ 30 min) was an independent risk factor for CVD. Our findings were highly consistent with those of the Sleep Heart Health Study[44], which suggested that regular long nappers (> 30 min) had a higher prevalence of incident CVD. Nonetheless, great heterogeneity still existed in terms of the effects of various napping durations. Specifically, a meta-analysis of 11 prospective cohort studies[45] presented that a long daytime nap (≥ 60 min/day) was associated with an increased risk of CVD, whereas a short nap (< 60 min) was not. Furthermore, two Chinese studies from the Dongfeng-Tongji cohort[26,46] linked elevated CVD risk with napping of 90+ min/day only. This discrepancy in nap-CVD associations across studies remained largely unclear but could possibly be related to the different study designs, nap categorizations, or populations[10].

Increasing research interest has been focused on daytime napping in studies assessing risk factors of HTN, while epidemiologic findings to date for nap-HTN associations were far from consistent. The Alzheimer Caregiver Coping Study from California[47] reported that daytime naps were not significantly associated with the odds of having HTN, and a cross-sectional study in Beijing, China,[28] reported a remarkably lower HTN risk in participants with 1 h of napping. On the contrary, a meta-analysis of nine observational studies[48] summarized that a long afternoon nap (> 30 min) was possibly associated with a higher risk of HTN. Similar results were also identified in our analysis in that elevated risk of HTN

Table 2. Effects of daytime napping on cardiovascular disease

Diseases	Groups	Age- and gender-adjusted model			Multivariate model[a]		
		HR (95% *CI*)	*P* value	*P* for trend	HR (95% *CI*)	*P* value	*P* for trend
CVD				< 0.001			< 0.001
	0 min	1 (Ref)			1 (Ref)		
	< 30 min	1.17 (0.98 to 1.40)	0.087		1.07 (0.89 to 1.29)	0.448	
	30 to 60 min	**1.29 (1.14 to 1.46)**	< 0.001		**1.22 (1.08 to 1.39)**	0.002	
	≥ 60 min	**1.36 (1.18 to 1.57)**	< 0.001		**1.27 (1.09 to 1.47)**	0.002	
HTN				< 0.001			< 0.001
	0 min	1 (Ref)			1 (Ref)		
	< 30 min	1.12 (0.90 to 1.40)	0.308		1.04 (0.83 to 1.30)	0.752	
	30 to 60 min	**1.29 (1.12 to 1.50)**	0.001		**1.21 (1.04 to 1.41)**	0.012	
	≥ 60 min	**1.48 (1.25 to 1.75)**	< 0.001		**1.38 (1.16 to 1.65)**	< 0.001	
Stroke				0.140			0.137
	0 min	1 (Ref)			1 (Ref)		
	< 30 min	0.89 (0.61 to 1.30)	0.544		0.96 (0.65 to 1.42)	0.845	
	30 to 60 min	**1.39 (1.11 to 1.75)**	0.004		**1.39 (1.10 to 1.76)**	0.006	
	≥ 60 min	1.07 (0.80 to 1.43)	0.625		1.04 (0.77 to 1.40)	0.602	

Note. [a]We adjusted gender, age, BMI, ethnicity, marital status, residential region, geolocation, educational attainment, employment status, annual household income, physical activity, smoking status, alcohol consumption, and sleep duration. HR, hazard ratio; 95% *CI*, 95% confidence interval.

was associated with long napping duration (≥ 30 min). However, evidence was still conflicting on the effects of various napping durations on HTN risk in a few studies. For instance, the Dongfeng-Tongji Cohort study[12] and the cross-sectional study of CFPS[37] illustrated negative associations of daytime napping with HTN following a long napping duration of > 60 min per day only. Relevant researchers should pay more attention to the heterogeneous results regarding the effects of different napping durations.

Potential Effect Modifiers

Gender and age differences in associations of napping duration with CVDs have generated widespread interest in public health epidemiology, but findings were not well consistent. In the present study, we observed that a stronger nap-CVD association occurred in men, in line with the results of a British Regional Heart Study and an American community-based study on men[44,49]. However, our results revealed that HTN risk exists in both genders,

Table 3. Subgroup analysis for the association of nap duration with cardiovascular disease

Subgroup	Hazard ratio[a] (95% *CI*)			*P* for trend	*P* for interaction
	< 30 min	30 to 60 min	≥ 60 min		
Gender					0.640
Male (*n* = 6,676)	1.03 (0.75 to 1.41)	1.20 (0.98 to 1.46)	**1.38 (1.11 to 1.73)****	0.003	
Female (*n* = 7,030)	1.09 (0.87 to 1.37)	**1.25 (1.06 to 1.48)****	1.21 (0.98 to 1.49)	0.010	
Age, years					0.539
30–49 (*n* = 7,411)	1.11 (0.80 to 1.55)	**1.36 (1.08 to 1.73)****	1.23 (0.91 to 1.65)	0.028	
≥ 50 (*n* = 6,295)	1.08 (0.86 to 1.35)	**1.17 (1.01 to 1.37)***	**1.31 (1.10 to 1.56)****	0.001	
BMI, kg/m²					0.382
< 24 (*n* = 9,449)	1.22 (0.96 to 1.57)	**1.30 (1.10 to 1.54)****	**1.32 (1.08 to 1.62)****	0.001	
≥ 24 (*n* = 4,257)	0.97 (0.74 to 1.29)	1.15 (0.95 to 1.40)	1.24 (0.99 to 1.55)	0.036	
Residential region					0.191
Urban (*n* = 5,914)	1.00 (0.78 to 1.29)	1.08 (0.90 to 1.30)	1.09 (0.87 to 1.38)	0.344	
Rural (*n* = 7,792)	1.17 (0.89 to 1.53)	**1.34 (1.12 to 1.60)****	**1.41 (1.15 to 1.72)****	< 0.001	
Geolocation					0.043
North (*n* = 8,120)	1.06 (0.84 to 1.34)	**1.30 (1.11 to 1.53)****	**1.33 (1.11 to 1.60)****	< 0.001	
South (*n* = 5,586)	1.11 (0.81 to 1.51)	1.09 (0.88 to 1.35)	1.14 (0.86 to 1.51)	0.283	
Physical activity					0.189
Yes (*n* = 3,345)	1.10 (0.82 to 1.46)	1.11 (0.89 to 1.39)	1.01 (0.76 to 1.34)	0.642	
No (*n* = 10,361)	1.03 (0.80 to 1.32)	**1.26 (1.07 to 1.47)****	**1.38 (1.16 to 1.65)*****	< 0.001	
Smoking status					0.790
Yes (*n* = 5,356)	1.02 (0.71 to 1.46)	**1.34 (1.08 to 1.67)***	**1.42 (1.12 to 1.81)****	0.001	
No (*n* = 8,350)	1.10 (0.89 to 1.37)	**1.18 (1.01 to 1.38)***	1.20 (0.99 to 1.46)	0.020	
Alcohol consumption					0.007
Yes (*n* = 3,121)	1.29 (0.86 to 1.92)	1.11 (0.83 to 1.47)	**1.46 (1.08 to 1.97)***	0.031	
No (*n* = 10,585)	1.02 (0.83 to 1.26)	**1.26 (1.09 to 1.45)****	1.18 (0.99 to 1.43)	0.001	
Sleep duration, hours/night					0.168
< 7 (*n* = 5,599)	0.96 (0.69 to 1.33)	1.17 (0.96 to 1.42)	1.22 (0.97 to 1.52)	0.357	
≥ 7 (*n* = 8,072)	1.13 (0.90 to 1.42)	**1.30 (1.09 to 1.55)****	**1.30 (1.05 to 1.61)****	0.001	

Note. [a]We adjusted gender, age, BMI, ethnicity, marital status, residential region, educational attainment, employment status, annual household income, physical activity, smo, king status, alcohol consumption, and sleep duration. 95% *CI*, 95% confidence interval. $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

and this finding was incompletely supported by related studies. For instance, two nationwide cross-sectional studies have reported that extended afternoon napping was linked with HTN in women but not in men[27,37]. Gender discrepancies for HTN risk should be further explored in future investigations. Moreover, increasing evidence highlighted that the napping-associated CVD risks usually increase with age, especially in older groups ≥ 65 years[46,50]. However, in our study, significant effects of long daytime napping on CVD risks were profound in middle-aged adults, not only in the elderly. Future napping epidemiology research is still needed to focus on the effect modification by age.

Obesity predicts a broad range of health risks, including CVDs, HTN, diabetes, and lower quality of life[51,52]. Interestingly, our analysis found stronger nap-CVD associations in participants who were underweight. However, most studies demonstrated that obesity (BMI ≥ 24 kg/m^2) may amplify the adverse effects of naps on chronic diseases[26,53]. Besides, we observed nap-CVD associations varied

Table 4. Subgroup analysis for the association of nap duration with hypertension

Subgroup	Hazard ratio[a] (95% *CI*)			*P* for trend	*P* for interaction
	< 30 min	30 to < 60 min	≥ 60 min		
Gender					0.670
Male (*n* = 6,676)	0.87 (0.60 to 1.28)	1.18 (0.94 to 1.48)	1.42 (1.11 to 1.83)***	0.006	
Female (*n* =7,030)	1.12 (0.84 to 1.49)	1.24 (1.01 to 1.52)**	1.36 (1.06 to 1.73)**	0.006	
Age, years					0.092
30–49 (*n* = 7,411)	1.13 (0.76 to 1.69)	1.45 (1.09 to 1.92)***	1.46 (1.03 to 2.05)**	0.006	
≥ 50 (*n* = 6,295)	1.01 (0.77 to 1.33)	1.13 (0.95 to 1.35)	1.38 (1.13 to 1.69)***	0.003	
BMI, kg/m²					0.396
< 24 (*n* = 9,449)	1.18 (0.87 to 1.61)	1.26 (1.02 to 1.55)**	1.46 (1.14 to 1.85)***	0.001	
≥ 24 (*n* = 4,257)	0.95 (0.68 to 1.31)	1.20 (0.97 to 1.50)	1.38 (1.07 to 1.77)**	0.008	
Residential region					0.244
Urban (*n* = 5,914)	1.08 (0.80 to 1.44)	1.06 (0.85 to 1.31)	1.20 (0.92 to 1.57)	0.230	
Rural (*n* = 7,792)	0.97 (0.68 to 1.39)	1.37 (1.10 to 169)***	1.52 (1.20 to 1.92)****	< 0.001	
Geolocation					0.027
North (*n* = 8,120)	1.10 (0.82 to 1.47)	1.36 (1.11 to 1.66)***	1.58 (1.26 to 1.97)****	< 0.001	
South (*n* = 5,586)	1.99 (0.69 to 1.41)	1.08 (0.85 to 1.36)	1.15 (0.84 to 1.55)	0.351	
Physical activity					0.040
Yes (*n* = 3,345)	1.14 (0.82 to 1.58)	1.06 (0.81 to 1.38)	1.01 (0.73 to 1.41)	0.824	
No (*n*=10,361)	0.91 (0.66 to 1.24)	1.27 (1.06 to 1.53)**	1.57 (1.28 to 1.93)****	< 0.001	
Smoking status					0.538
Yes (*n* = 5,356)	0.84 (0.53 to 1.33)	1.34 (1.04 to 1.73)**	1.50 (1.14 to 1.99)***	0.002	
No (*n* = 8,350)	1.11 (0.86 to 1.44)	1.15 (0.95 to 1.39)	1.32 (1.05 to 1.65)**	0.015	
Alcohol consumption					0.272
Yes (*n* = 3,121)	1.25 (0.78 to 2.01)	1.23 (0.89 to 1.70)	1.56 (1.11 to 2.20)**	0.016	
No (*n* = 10,585)	0.98 (0.76 to 1.27)	1.21 (1.02 to 1.43)**	1.34 (1.09 to 1.64)***	0.004	
Sleep duration, hours/night					0.370
< 7 (*n* = 5,599)	0.86 (0.57 to 1.29)	1.13 (0.90 to 1.43)	1.34 (1.04 to 1.72)**	0.023	
≥ 7 (*n* = 8,072)	1.11 (0.85 to 1.46)	1.31 (1.06 to 1.62)**	1.41 (1.10 to 1.79)***	0.001	

Note. [a]We adjusted gender, age, BMI, ethnicity, marital status, residential region, educational attainment, employment status, annual household income, physical activity, smoking status, alcohol consumption, and sleep duration. 95% *CI*, 95% confidence interval. *P < 0.05; **P < 0.01; ***P < 0.001; ****P < 0.0001.

by region, with higher risks occurring in rural areas and northern China. Similar associations were also observed in a cross-sectional rural study of middle-aged Chinese populations from Henan province[54]. In contrast to this nationwide study, two regional surveys among community-based rural elderly populations in Beijing[28] and Hunan[55] reported that long napping duration was not associated with an increased risk of HTN. A possible explanation for this discrepancy could be the great heterogeneity (e.g., age and napping habits) between study populations. Our findings on geographical variations may have significant public health implications for targeted patterns of naps and vulnerable populations, locally and regionally.

Nap-CVD associations could be possibly modified by physical activity, smoking, and alcohol drinking habits. As regards physical activity, we observed higher nap-associated risks in physically inactive persons. However, a previous study with Dongfeng-Tongji Cohort noted slightly stronger effects of long daytime napping on incident coronary heart diseases in adults who are physically active[46]. This inconsistency across studies might be attributable to discrepancies in regions and demographic characteristics. Our results also indicate that long daytime napping was associated with cardiovascular incidences across smoking groups, consistent with the results of a previous study of a predominantly American population with various smoking profiles[44]. Among alcohol drinkers, only the association with ≥ 60 min napping was noted in our study, and no well-documented evidence to date has been detected regarding napping-CVD association variations by drinking status. Further investigations are needed to fully clarify the potential modifying effect of alcohol consumption.

The combined effect of daytime napping with nighttime sleep on CVD was a common concern in epidemiologic research. A recent cohort study with 116,632 participants from 21 countries revealed that midday napping was linked to increased risks of major CVD events in those with > 6 h of nighttime sleep[11]. Two Chinese analyses also reported higher risks of stroke in participants who napped ≥ 1 h and slept ≥ 9 h/night[26,56]. The result of our subgroup analysis of nap-CVD association by nighttime sleep was largely consistent with the aforementioned research, suggesting a possibly higher nap-associated risk for CVD among adults with excessively long nighttime sleep. Furthermore, the nap-associated risk of HTN was found in those who slept > 7 h/night in our analysis. However, existing epidemiologic evidence generally focused on the association of daytime napping with HTN only, and no sufficient studies have considered nocturnal sleep as a potential effect modifier. More sophisticated nap-CVD investigations are greatly necessary to distinguish the independent and combined effects of afternoon napping and nighttime sleep on human health.

Possible Biological Mechanism

The mechanism underlying the association of daytime napping with CVD and HTN is not completely clear. Several mechanisms may explain the associations between napping and major CVD events. First, fluctuations in blood pressure and heart rate caused by the excitement of the sympathetic nervous system after a nap in the morning or noon may be closely related to an increased CVD risk[57-59]. Second, inflammation might mediate the relationship between frequent daytime napping and poor health outcomes[60,61]. Third, long napping may regulate the endocrine hormones and body metabolisms, such as insulin and leptin, leading to alterations in glucose metabolism and appetite that may accelerate the development of diabetes and obesity[14,62].

Limitation

This study has some limitations. First, the CFPS survey only released data at baseline and of three subsequent waves of follow-up during the preparation of this work. Therefore, our napping-CVD analysis is limited to a relatively shorter follow-up period. Second, self-reported sleep information from the questionnaire may have recall bias compared with objective biological sleep. However, objective measurements of nighttime sleep and naps are not feasible in large prospective population studies, and the self-management questionnaire is the most commonly used method to assess sleep and disease, which have been reported in many studies[11,44,49]. Third, the ascertainment of CVD outcomes in our study may lead to null findings because individuals with events may be included in the non-event group based on self-reported diagnoses of CVDs. However, we still found a significant positive association between daytime napping and CVD, and the findings may provide valuable hints for further studies. Finally, some confounders were not included for adjustment in our study, such as dietary factors (salt consumption, etc.)[63], psychological status (anxiety, depression, etc.)[64], biomarker (CRP, IL-6, TC, HDL-C, etc.),[61] and

sleep disorders (sleep apnea, insomnia, sleep quality, etc.)[65], and these factors and other undetected covariates might be potential confounders related to CVD or HTN.

CONCLUSION

Briefly, this study provided strong evidence that daytime napping was associated with increased risks of CVD and HTN in Chinese adults. Specifically, significant associations of CVD and HTN with naps ≥ 30 min per day were found, but not with short naps (< 30 min). Higher nap-associated risks were observed in adults with BMI of < 24 kg/m^2, persons who are physically inactive, smokers, and sleepers of ≥ 7 h/night. Significant effect modification by geolocation was also identified in our analysis. These findings may have important implications in public health policymaking to improve the prevention and management of CVDs and provide scientific guidance for reasonable sleep arrangements. More future studies are warranted worldwide to focus on the long-term effects of daytime napping on human health.

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AUTHORS CONTRIBUTIONS

ZHANG Yun Quan conceived and designed the study. WANG Lu, WANG Ke, ZHOU Pei Xuan, SHU Hai Uan, and WANG Kai collected and cleaned the data. WANG Lu and ZHANG Yun Quan performed the data analysis and drafted the original manuscript. WANG Ke, LIU Lin Jiong, and ZHANG Yuan Yuan helped revise the manuscript. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare they have no conflicts of interest.

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Supplementary Table S1. Subgroup analysis for the association of nap duration with stroke

Subgroup	Hazard ratio[a] (95% *CI*)			*P* for trend	*P* for interaction
	< 30 min	30 to 60 min	≥ 60 min		
Gender					0.339
Male (*n* = 6,676)	0.81 (0.42 to 1.58)	1.36 (0.96 to 1.91)	1.17 (0.78 to 1.75)	0.183	
Female (*n* = 7,030)	1.08 (0.67 to 1.75)	**1.39 (1.01 to 1.93)***	0.86 (0.54 to 1.37)	0.549	
Age, years					0.815
30–49 (*n* = 7,411)	0.67 (0.26 to 1.71)	1.20 (0.70 to 2.04)	0.75 (0.36 to 1.54)	0.810	
≥ 50 (*n* = 6,295)	1.07 (0.70 to 1.64)	**1.43 (1.10 to 1.86)****	1.13 (0.81 to 1.58)	0.077	
BMI, kg/m^2					0.464
< 24 (*n* = 9,449)	0.71 (0.41 to 1.22)	**1.39 (1.06 to 1.84)***	0.91 (0.63 to 1.33)	0.417	
≥ 24 (*n* = 4,257)	1.47 (0.82 to 2.61)	1.30 (0.84 to 2.02)	1.30 (0.77 to 2.19)	0.227	
Residential region					0.351
Urban (*n* = 5,914)	0.88 (0.49 to 1.57)	1.18 (0.81 to 1.73)	0.99 (0.59 to 1.67)	0.653	
Rural (*n* = 7,792)	1.05 (0.62 to 1.77)	**1.59 (1.17 to 2.16)****	1.09 (0.75 to 1.59)	0.108	
Geolocation					< 0.001
North (*n* = 8,120)	0.94 (0.60 to 1.46)	**1.32 (1.00 to 1.74)***	0.89 (0.63 to 1.26)	0.695	
South (*n* = 5,586)	0.95 (0.43 to 2.13)	1.33 (0.84 to 2.13)	1.44 (0.78 to 2.65)	0.139	
Physical activity					0.787
Yes (*n* = 3,345)	0.84 (0.42 to 1.69)	1.51 (0.98 to 2.33)	0.81 (0.42 to 1.53)	0.570	
No (*n* = 10,361)	1.07 (0.67 to 1.71)	1.31 (0.98 to 1.73)	1.08 (0.77 to 1.52)	0.240	
Smoking status					0.380
Yes (*n* = 5,356)	0.73 (0.33 to 1.61)	**1.61 (1.11 to 2.34)***	1.19 (0.76 to 1.86)	0.104	
No (*n* = 8,350)	1.08 (0.69 to 1.69)	1.29 (0.95 to 1.75)	0.91 (0.60 to 1.38)	0.602	
Alcohol consumption					0.751
Yes (*n* = 3,121)	0.69 (0.24 to 1.97)	1.31 (0.79 to 2.17)	1.12 (0.64 to 1.99)	0.449	
No (*n* = 10,585)	1.04 (0.68 to 1.58)	**1.43 (1.10 to 1.86)****	1.02 (0.71 to 1.45)	0.165	
Sleep duration, hours/night					0.364
< 7 (*n* = 5,599)	0.70 (0.36 to 1.37)	0.97 (0.69 to 1.37)	0.84 (0.55 to 1.26)	0.528	
≥ 7 (*n* = 8,072)	1.12 (0.69 to 1.80)	**1.86 (1.35 to 2.57)*****	1.20 (0.78 to 1.86)	0.012	

Note. [a]We adjusted gender, age, BMI, ethnicity, marital status, residential region, educational attainment, employment status, annual household income, physical activity, smoking status, alcohol consumption, and sleep duration. 95% *CI*, 95% confidence interval. $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

Supplementary Table S2. Sensitive analysis of hazard ratios (95% *CI*s) for incident CVDs associated with napping duration, by excluding those who developed outcomes in 1 year after baseline survey, study participants aged > 75 years and participants who had changed daytime-napping behaviors during follow-ups

Diseases	Groups	HR (95% *CI*)			
		Main model	Model 1	Model 2	Model 3
CVD					
	< 30 min	1.07 (0.89, 1.29)	1.10 (0.92, 1.33)	1.10 (0.91, 1.33)	**1.25 (1.03, 1.51)***
	30 to 60 min	**1.22 (1.08, 1.39)****	**1.23 (1.09, 1.40)****	**1.25 (1.10, 1.42)****	**1.38 (1.20, 1.57)*****
	≥ 60 min	**1.27 (1.09, 1.47)****	**1.28 (1.11, 1.48)*****	**1.33 (1.15, 1.54)*****	**1.42 (1.22, 1.66)*****
HTN					
	< 30 min	1.04 (0.83, 1.30)	1.04 (0.83, 1.30)	1.05 (0.84, 1.31)	1.14 (0.90, 1.45)
	30 to 60 min	**1.21 (1.04, 1.41)***	**1.22 (1.05, 1.42)****	**1.23 (1.06, 1.44)****	**1.36 (1.16, 1.60)*****
	≥ 60 min	**1.38 (1.16, 1.65)*****	**1.41 (1.19, 1.67)*****	**1.44 (1.12, 1.71)*****	**1.57 (1.31, 1.88)*****
Stroke					
	< 30 min	0.96 (0.65, 1.42)	1.01 (0.69, 1.49)	1.04 (0.71, 1.54)	1.06 (0.70, 1.59)
	30 to 60 min	**1.39 (1.10, 1.76)****	**1.40 (1.11, 1.77)****	**1.43 (1.13, 1.81)****	**1.52 (1.19, 1.95)*****
	≥ 60 min	1.04 (0.77, 1.40)	1.06 (0.79, 1.42)	1.09 (0.81, 1.47)	1.14 (0.84, 1.55)

Note. Abbreviations: HR, hazard ratio; *CI*, confidence interval; CVDs, cardiovascular diseases; HTN, hypertension. Model 1: restricting our study outcomes beyond the initial first year. Model 2: restricting participants aged < 75 years. Model 3: restricting the analysis to adults who had not changed daytime-napping behaviors during follow-ups. $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.