Association Between Sleep Duration and Hypertension in Middle-aged and Elderly Population in China

by

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Thesis submitted in partial fulfillment of
the requirements for the degree of Master of Science in the
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2021

ABSTRACT

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Abstract

Hypertension is one of the most important global public health problems today, especially among middle-aged and older adults. Numerous studies have been done to explore the risk factors of hypertension, among which sleep duration, has aroused immense attention. However, no consistent conclusion has been drawn and the empirical evidence from China was scarce. This study aims to investigate the association between sleep duration and the onset of hypertension among Chinese middle-aged and older adults based on China and Health Retirement Longitudinal Study (CHARLS).

The study conducted a survival analysis of participants from CHARLS from 2011 to 2015. A total of 7655 participants were included in this study. Information on self-reported sleep duration, hypertension, quality of sleep, nap, age, sex, smoking, drinking, health insurance, body mass index (BMI), Hukou status, marital status, highest education level, diabetes or high blood sugar, and dyslipidemia were collected. Kaplan-Meier estimate and cox proportional hazard models were used to estimate the association between sleep duration and the onset of hypertension. Subgroup analysis was conducted to evaluate the age difference.

There was no significant association between self-reported sleep duration and hypertension in the whole sample, but in the subgroup of older adults aged more than 60, the cox models reported lower hazard ratios (HRs) for those with sleep duration 6-7 hours than the reference group (7-8 hours) (HR=0.758, 95% CI 0.606-0.948).

Although no significant relationship was found between sleep duration and hypertension among the middle-aged and older Chinese population, this study revealed that sleep for 6-7 hours was a protective factor of hypertension among older adults. The age difference should be taken into consideration when making recommendations of sleep duration in the future.

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Acknowledgements

My deepest gratitude goes first and foremost to Professor Lijing Yan, my supervisor, for her constant encouragement and instructions. She has walked me through all the stages of the writing of this thesis. Without her illuminating guidance, this thesis could not have reached its present form. Secondly, I also feel great thanks to Professor Chenkai Wu and Professor Truls Ostbye who have instructed and helped me a lot in the methods part.

1. Introduction

Hypertension is a serious medical condition and chronic disease, which is the risk factor of many serious diseases, such as heart failure, stroke, vision loss, and chronic kidney disease. According to epidemiological data, the prevalence of hypertension worldwide in 2010 was 31.9% among adults, which led to 1.39 billion people with hypertension (Mills et al., 2020). About 20% of women and 25% of men all over the world had high blood pressure in 2015 (WHO, 2020). In China, the prevalence was lower than the overall prevalence worldwide. According to the China Hypertension Survey from 2012 to 2015, 23.2% of Chinese adults (about 244.5 million) had hypertension. Nevertheless, only 46.9% of hypertensive adults were aware of their condition, 40.7% were taking prescribed antihypertensive drugs, and 15.3% had controlled the condition (Wang Zengwu et al., 2018). The prevalence of hypertension in China has also increased rapidly in the past decades. Hypertension is a major disease burden and a serious public health issue in China and worldwide.

1.1 Risk Factors for Hypertension

There are many genetic and environmental factors proven to increase the risk of hypertension. Previous studies confirmed hundreds of genetic loci or mapped genes that underlie genetic susceptibility to hypertension, especially essential hypertension (Patel et al., 2017). A study in the Japanese population revealed that there were three gene mutations associated with hypertension, including two mutations in G protein β3

subunit gene and CC chemokine receptor 2 gene among men and one mutation in tumor necrosis factor α gene among women (Izawa Hideo et al., 2003). Genetic risk factors lead to a family history of hypertension across generations.

Compared with genetics, more efforts were paid to investigate and identify the environmental factors that cause a higher risk of hypertension. Previous studies found that short-term and long-term exposure to ambient air pollutants, such as O3, CO, NOx, PM10, and PM2.5, might increase the risk of hypertension (Cai Yuanyuan et al., 2016; Coogan Patricia F. et al., 2012; Sanidas et al., 2017). Psychological and mental health was also found to be associated with hypertension. Several epidemiological studies showed that anger, stress, anxiety, and depression might be predictive of later incidence of hypertension (Markovitz et al., 1993; Matthews Karen A. et al., 2004).

In addition, dietary and lifestyle factors were showed to play an important role in the development and management of hypertension. Although the impacts of these risk factors vary among people with different characteristics, such as sex, age, region, and race, there are some common dietary and lifestyle factors identified to increase the risk of hypertension, including being overweight, physical inactivity, high sodium intake and low potassium intake (Forman et al., 2009; Geleijnse et al., 2004).

1.2 Sleep Health

Sleep is an essential part of human life and about 1/3 of a lifetime is spent in sleep for most people. Sleep health can be measured from five dimensions, including

quality, alertness/sleepiness/napping, timing, efficiency, and duration. (Buysse, 2014). Based on the five dimensions, good sleep health can be defined as a sleep condition with subjective satisfaction, appropriate timing, adequate duration, high efficiency, and low sleepiness at working hours. National sleep foundation the United States recommended that young and middle-aged adults should sleep for seven to nine hours per day and older adults should spend seven to eight hours in sleep (Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, Hazen, Herman, Adams Hillard, et al., 2015).

Epidemiological data showed that short sleep duration was becoming a serious health issue among children, adolescents, and adults and vulnerable population included night shift workers, people with low household income and education, and students (Centers for Disease Control and Prevention (CDC), 2012; Luckhaupt et al., 2010; Stamatakis et al., 2007; Wheaton et al., 2018). Inadequate sleep duration can lead to a series of health outcomes. Previous studies found that inappropriate sleep duration was associated with higher mortality, obesity, metabolic syndrome, diabetes, hypertension, cardiovascular diseases, and impaired neurobehavioral performance.

There were some interventions proven to improve the timing of sleep and sleep duration. Frequently used non-pharmacological interventions included stress management and relaxation practice, stimulus control (avoiding activities on the bed except for sleeping and sexual activity), controlled breathing, sleep hygiene, and physical activity (Murawski et al., 2018). These single intervention components were

often used as a therapy package to deal with sleep problems and showed effectiveness in clinical trials (Espie et al., 2019; Friedrich & Schlarb, 2018; Lancee et al., 2015).

1.3 Sleep Duration and Hypertension

Many studies explored the association between sleep duration and hypertension, but the results were inconsistent. Some studies found that there was a "U"-shaped association between hours of sleep duration and hypertension. Fang (2012) conducted a cross-sectional study among US adults and found that sleep < 7 or ≥10 hours per day was associated with a higher likelihood of hypertension compared with 8 hours per day. Another study conducted in Japanese older adults aged no less than 70 years also revealed that there was a "U"-shaped relationship between sleep duration and blood pressure, where participants with sleep duration <6 hours or >8 hours had a higher systolic blood pressure than those who slept for 6-8 hours (Sasaki et al., 2016). A meta-analysis included thirteen studies and also found that there were increased ORs for those with ≤5 hours and ≥9 hours of sleep duration compared with 7 hours (Wang Yan et al., n.d.).

Some studies found that only short sleep duration was associated with hypertension. A prospective study among middle-aged US adults showed that short sleep duration was associated with increased blood pressure and incident hypertension (Knutson et al., 2009). Similarly, a prospective study among middle-aged and older Korean adults reported that short sleep duration increased the incidence of

hypertension, compared with a sleep duration of 6 to 7.9 hours while long sleep duration didn't show a significant difference (Yadav et al., 2017). Negative results were also reported in some studies. Two cross-sectional studies among the elderly separately in France and Netherlands reported that there was no significant association between sleep duration and the prevalence of hypertension (Sforza et al., 2014; van den Berg et al., 2007).

Studies indicated that sex and age differences existed in the relationship between sleep duration and hypertension. In a prospective study, Cappuccio (2007) investigated the impact of sex on this association among British middle-aged civil servants and concluded that short sleep duration (<5 hours) was associated with a greater likelihood of hypertension in women, compared with those of 7 hours, while no significant association was found in men.

A cross-sectional study among the South Korean population found that young and middle-aged participants with short sleep duration (<5 hours) had a higher prevalence of hypertension compared with those who slept for 7 hours, while no significantly higher prevalence was found among older adults (Kim & Jo, 2010). Similarly, another cross-sectional study among US adults also found that short sleep duration (5 hours) was a risk factor for adults younger than 70 years (Grandner Michael et al., n.d.). In terms of the effect of age and sex, Fang (2012) reported more detailed results that both short sleep (<6 hours for men and <8 hours for women) and long sleep (>10 hours) were risk factors for young adults aged less than 45 years, while only short

sleep (<6 hours) was a risk factor for middle-aged men and older women and only long sleep (>10 hours) for middle-aged women.

There were also some efforts to investigate the association between sleep duration and hypertension and the effects of age and sex in the Chinese population. Guo (2016) conducted a cross-sectional analysis based on wave 1 of China Health and Retirement Longitudinal Study (CHARLS) and reported that short sleep duration (<6 hours) was a risk factor for the whole sample (middle-aged and older adults) compared with sleep duration of 7-8 hours, while no significant relationship was found for long sleep duration. In this study, sex and age-specific analysis showed that short (<6 hour and 6-7 hours) and long sleep duration (8-9 hours) were associated with a higher prevalence of hypertension for middle-aged men but not women, while long sleep duration (>9 hours) was observed to be significantly associated with hypertension only in middle-aged women. Similarly, a prospective cohort study included participants from China Health and Nutrition Survey (CHNS) and found that only short sleep duration (≤7 hours) was associated with a higher incidence of hypertension (Feng et al., 2019). However, three cross-sectional studies using data from CHNS investigated the association between sleep duration and prevalence of hypertension in the whole sample and stratified by age or/and sex and they all reported negative results in the whole sample (Li et al., 2019; Sun et al., 2016; Wu et al., 2016). In these three studies, short sleep duration was reported as a risk factor of hypertension respectively in middle-aged females, young adults (18-44 years), and older men. A prospective cohort study among

adults aged 40-70 years found that although a short sleep duration (<4.9 hours) increased the hazards of hypertension among adults aged 40-55 years, no significant association was found among adults aged 55-70 years (Wu et al., 2016).

1.4 Research Gap and Objectives of the Present Study

Based on the literature review above, several research gaps could be identified. Firstly, there has not reached an agreement on the relationship between sleep duration and hypertension, especially in the Chinese population. Secondly, although many studies focused on the age and sex differences in the association between sleep duration and hypertension, the conclusions of previous studies were inconsistent. Thirdly, longitudinal studies were insufficient as most of the epidemiological studies used cross-sectional data.

Based on the research gap identified, the study aims to investigate the association between self-reported sleep duration and the onset of hypertension among middle-aged and older adults in China and explore the impact of sex and age on the association.

2. Methods

2.1 Study Population

This study used the data from CHARLS. CHARLS was designed as a nationwide longitudinal study to respond to the challenge of population aging in China so it only recruited Chinese residents aged no less than 45 years. CHARLS adopted multistage random sampling. At the first stage, CHARLS randomly selected 150 countries/districts from 28 provinces, autonomous regions, and municipalities, with the use of Probability Proportional to Size (PPS) sampling. At the second stage, three villages/urban communities were selected randomly in every county/district with the use of PPS sampling. At the third stage, a certain number of households were selected randomly in every village/urban community. The CHARLS national baseline survey was conducted in 2011-2012, which included 17708 participants from 450 villages/urban communities, 150 countries/districts, 28 provinces across the country. Wave 2 was conducted in 2013, wave 3 in 2015, and wave 4 in 2018. The response rate in the following three waves were 88.3%, 87.2%, and 86.5%, respectively.

The present study used baseline data from wave 1 and follow-up data from wave 2 and wave 3, except for wave 4 which did not release data of blood pressure measurements. As a longitudinal study to examine the association between sleep duration and the onset of hypertension, the study excluded people who had hypertension in the baseline survey, defined as systolic blood pressure ≥ 140 or diastolic

blood pressure ≥ 90 mmHg, self-reported physician-diagnosed hypertension, or self-reported known hypertension. A total of 17,708 individuals were included in the baseline survey. Participants who aged younger than 45 years old (n=367), had missing data of hypertension (1216), had hypertension (n=6591), did not report sleep duration (n=1039), reported unreasonable value of demographic, or biomarker variables (n=1914) in wave 1 were excluded, leading to an analytic sample of 7,655. The percentage of participants lost to follow-up was 14.1%. 343 participants were only lost to follow-up in wave 3, 493 participants who were only lost to follow-up in wave 2, and 247 participants who were lost to follow-up in wave 2 and 3.

2.2 Predictors

Self-reported sleep duration at night was reported in the baseline survey. Participants were asked, "During the past month, how many hours of actual sleep did you get at night (average hours for one night)? (This may be shorter than the number of hours you spend in bed.)". Their answers were numbers with at most two decimal places, ranging from 0.00 to 24.00. Subjects were divided into five categories according to sleep duration: <6 hours, 6-7 hours, 7-8 hours, 8-9 hours, and ≥ 9 hours. Sleep duration <7 hours and ≥8 hours were defined as short sleep duration and long sleep duration, respectively.

2.3 Outcomes

Hypertension was defined as systolic blood pressure ≥ 140 or diastolic blood pressure ≥ 90 mmHg, self-reported physician-diagnosed hypertension, or self-reported known hypertension. Systolic blood pressure and diastolic blood pressure were measured three times at 45s intervals by trained nurses using an Omron HEM-7200 monitor (Omron (Dalian) Co, Dalian, China). The mean of these measurements was calculated. Self-reported physician-diagnosed hypertension was obtained with the question "have you been diagnosed with hypertension by a doctor?". Self-reported known hypertension was obtained with the question "do you know if you have hypertension?".

The onset of hypertension, defined as mentioned previously, or no incident hypertension in wave 2 or wave 3. The timing of developing hypertension was assumed to be the time of the follow-up survey. The month of the interview in the three waves was used to calculate survival time. Considering that the percentage of participants lost to follow-up reached 14.1%, they were were included in the analysis and given a survival time. For those who were only lost to follow-up in wave 3, the interval between the interview at baseline and in wave 2 was used as survival time. For those who were only lost to follow-up in wave 2, the interval between the interview at baseline and in wave 3 was used as survival time. For those who were lost to follow-up in wave 2 and 3, their survival time was given a small value of 0.1 months, based on the assumption that the short time was not sufficient for them to develop hypertension.

2.4 Covariates

Based on the literature review, potential confounding factors, which might be related to both predictors and outcomes, including quality of sleep, nap, age, sex, smoking, drinking, health insurance, body mass index (BMI), Hukou status (household registration), marital status, highest education level, diabetes or high blood sugar and dyslipidemia. Quality of sleep was obtained with the scale "my sleep was restless." The response scale contained 4 options: 1) rarely or none of the time (<1 day), 2) some or a little of the time (1-2 days), 3) occasionally or a moderate amount of the time (3-4 days), and 4) most or all the time (5-7 days). Afternoon nap was assessed by asking "during the past month, how long did you take a nap after lunch (minutes)?". Age of participants was divided into middle age (45-60 years) and older age (≥60 years).

Smoking status was divided into never smoking, ever smoking, and currently smoking according to participants' response to "have you ever chewed tobacco, smoked a pipe, smoked self-rolled cigarettes, or smoked cigarettes/cigars?" and "do you still have the habit or have you totally quit?". Drinking status was assessed by asking "Did you drink any alcoholic beverages, such as beer, wine, or liquor in the past year?" and "how often?". The responses were categorized into no, drinking less than once a month, and drinking more than once a month. BMI was calculated by weight and height of participants measured by trained nurses using a Seca 213 height meter (Seca, (Hangzhou) Co, Hangzhou, China) and an Omron HN-286 weight scale (Krell (Yangzhou), Yangzhou, China).

Health insurance, such as urban employee medical insurance, urban resident medical insurance, new cooperative medical insurance, and no insurance, was recoded as yes or no. Hukou status was categorized as agricultural hukou, non-agricultural hukou, and others (unified residence hukou and not having hukou). Marital status was recoded as married (married with spouse present, married with spouse present, separated, and widowed) and never married or divorced. The highest education level was recoded as illiterate, primary (not finishing primary school but capable of reading or writing, sishu, and elementary school), middle/high/vocational school (middle school, high school, and vocational school), and college and higher (two/three-year college/associate degree, four-year college/bachelor's degree, and post-graduate / master's degree).

2.5 Statistical Analysis

Basic characteristics of participants were shown as mean (SD) for continuous variables and counts (proportions) for categorical variables, stratified by sleep duration. The difference in continuous variables was examined by one-way ANOVA. A Chi-square test was utilized to examine the difference in categorical variables. ANOVA was used to examine the difference in the proportion of incidence of hypertension in different groups of sleep duration in the whole sample and participants stratified by sex or age.

A comparative analysis of the basic characteristics between participants included and those excluded due to missing sleep duration and unreasonable values was conducted to evaluate whether there was selection bias when excluding those participants.

The relationship between sleep duration and onset of hypertension was conducted by survival analysis. The follow-up time was reported in the whole sample. The incidence rate of hypertension was reported in the whole sample and stratified by age and sex. A Kaplan-Meier plot was drawn, and a Log-Rank test was conducted to identify whether there was a difference in incidence rate between the five sleep duration groups.

Six Cox proportional hazard models were used to estimate the association between sleep duration and the onset of hypertension. Participants with a sleep duration of 7-8 hours were chosen as the reference group. Hazard ratio and 95% confidence interval were used to measure the relative risk of hypertension. Model 1 only included sleep duration and hypertension. Model 2 adjusted for quality of sleep and nap. Model 3 adjusted for quality of sleep, nap, age, and sex. Model 4 adjusted for quality of sleep, nap, age, sex, smoking, drinking, health insurance, BMI, Hukou status, marital status, highest education level, diabetes, or high blood sugar, and dyslipidemia. To examine the sex- and the age-specific relationship between sleep duration and hypertension models 5 and 6 added interaction of sleep duration and age and interaction of sleep duration and

sex to 4, respectively. The only age difference was found in model 5, so a cox model was performed on the total study sample stratified by age.

All analyses were conducted using Stata 14.0 (Stata Corp, Tex, USA) with a significance level of 0.05 of two sides.

3. Results

3.1 Basic characteristics of participants

A total of 7,655 middle-aged and older adults were included in the present study. The basic characteristics of the study population were presented in Table 1. Among the whole sample, the proportion of participants who slept for <6, 6-7, 7-8, 8-9, ≥9 hours per night were 28.4%, 21.4%, 20.4%, 21.8%, and 8.0% respectively. The mean duration for a nap after lunch was 31.5 minutes. The mean age was 57.6 years old, and the proportion of males was 49.0%.

Participants with shorter sleep duration were more likely to suffer from restless night sleep. Participants with longer night sleep duration tended to take a long nap after lunch. Compared with men, women were more likely to have a short sleep duration of less than 6 hours (45.7% vs. 54.3%). Participants with a sleep duration of <6 hours or ≥9 hours had a lower BMI compared with those who slept for 6-9 hours each night. Short or long sleep duration was more common among drinkers than non-drinkers. In terms of social status, non-agricultural participants and those with higher educational status tended to have a sleep duration of 7-8 hours. No significant differences in hours slept were found in smoking, health insurance, marital status, diabetes, and dyslipidemia.

Table 1: Basic characteristics of participants.

Characteristics	Total	Sleep duration category (hours/night)					p-value
		<6	6-7	7-8	8-9	≥9	
N (%)	7655	2176 (28.4%)	1639 (21.4%)	1559 (20.4%)	1669 (21.8%)	612 (8.0%)	<0.01
Sleep was restless							<0.01
<1 day	3819 (50.2%)	436 (20.2%)	775 (47.6%)	959 (61.9%)	1189 (71.5%)	460 (75.8%)	
1-2 days	1191 (15.6%)	316 (14.6%)	329 (20.2%)	275 (17.7%)	207 (12.5%)	64 (10.5%)	
3-4 days	1138 (15.0%)	463 (21.4%)	319 (19.6%)	179 (11.5%)	138 (8.3%)	39 (6.4%)	
5-7 days	1463 (19.2%)	948 (43.8%)	206 (12.6%)	137 (8.8%)	128 (7.7%)	44 (7.2%)	
Nap, mean (SD)	31.5 (42.6)	25.5 (39.5)	31.1 (40.7)	33.1 (41.4)	35.9 (45.6)	38.0 (49.0)	<0.01
Age, mean (SD)	57.6 (9.0)	59.1 (9.1)	57.3 (8.7)	56.1 (8.2)	57.0 (9.2)	58.1 (9.9)	<0.01
Sex							<0.01
Male	3750 (49.0%)	994 (45.7%)	813 (49.7%)	787 (50.5%)	860 (51.6%)	296 (48.5%)	
Smoking							0.30
Never	4552 (59.5%)	1331 (61.2%)	969 (59.1%)	904 (58.0%)	971 (58.2%)	377 (61.6%)	
Ever	607 (7.9%)	171 (7.9%)	136 (8.3%)	113 (7.2%)	142 (8.5%)	45 (7.4%)	
Current	2496 (32.6%)	674 (31.0%)	534 (32.6%)	542 (34.8%)	556 (33.3%)	190 (31.0%)	
Drinking							0.04
No	5025 (65.6%)	1481 (68.1%)	1056 (64.4%)	995 (63.8%)	1072 (64.2%)	421 (68.8%)	
Less than once a month	659 (8.6%)	166 (7.6%)	162 (9.9%)	141 (9.0%)	144 (8.6%)	46 (7.5%)	
More than once a month	1971 (25.7%)	529 (24.3%)	421 (25.7%)	423 (27.1%)	453 (27.1%)	145 (23.7%)	
Medical insurance							0.48
Yes	7153 (93.7%)	2036 (93.7%)	1534 (93.9%)	1467 (94.4%)	1545 (92.8%)	571 (93.6%)	
BMI, mean (SD)	22.8 (3.9)	22.4 (3.6)	23.0 (3.6)	23.1 (3.5)	23.1 (4.9)	22.6 (3.8)	<0.01
Hukou							<0.01

Non-agriculture	6331 (82.7%)	1883 (86.5%)	1292 (78.8%)	1237 (79.4%)	1381 (82.7%)	538 (87.9%)	
Agriculture	1282 (16.7%)	284 (13.1%)	339 (20.7%)	310 (19.9%)	275 (16.5%)	74 (12.1%)	
Others	41 (0.5%)	9 (0.4%)	8 (0.5%)	11 (0.7%)	13 (0.8%)	0 (0.0%)	
Marital status							0.98
Never married or divorced	118 (1.5%)	34 (1.6%)	27 (1.6%)	24 (1.5%)	23 (1.4%)	10 (1.6%)	
Married	7537 (98.5%)	2142 (98.4%)	1612 (98.4%)	1535 (98.5%)	1646 (98.6%)	602 (98.4%)	
Highest education level							<0.01
Illiterate	1957 (25.6%)	682 (31.3%)	361 (22.0%)	323 (20.7%)	390 (23.4%)	201 (32.8%)	
Primary	3137 (41.0%)	959 (44.1%)	651 (39.7%)	601 (38.6%)	686 (41.1%)	240 (39.2%)	
Middle/high/vocational school	2430 (31.8%)	518 (23.8%)	589 (35.9%)	598 (38.4%)	558 (33.5%)	167 (27.3%)	
College or higher	129 (1.7%)	17 (0.8%)	38 (2.3%)	36 (2.3%)	34 (2.0%)	4 (0.7%)	
Diabetes							0.36
Yes	281 (3.7%)	85 (3.9%)	57 (3.5%)	56 (3.6%)	53 (3.2%)	30 (4.9%)	
Dyslipidemia							0.99
Yes	383 (5.1%)	108 (5.1%)	84 (5.2%)	76 (5.0%)	82 (5.0%)	33 (5.5%)	

3.2 Comparison between Participants Included and Those Excluded Due to Missing Sleep Duration and Unreasonable Values

As shown in Table 2, there were differences in terms of sleep quality, smoking, medical insurance, BMI, Hukou, marital status, and highest education level and diabetes between participants included and those excluded due to missing sleep duration. The participants included had more smokers, a higher proportion of medical insurance, higher BMI, higher proportion of non-agricultural Hukou, higher married proportion, lower education level, and a higher proportion of diabetes than those excluded due to missing sleep duration.

Table 2: Comparison of basic characteristics between participants included and those excluded.

Characteristics	Total	Included or not		p-value
		Included	Excluded	
N (%)	10608	7655	1953	
Sleep was restless				<0.05
<1 day	4755 (50.1%)	3819 (50.2%)	936 (49.6%)	
1-2 days	1540 (16.2%)	1191 (15.6%)	349 (18.5%)	
3-4 days	1418 (14.9%)	1138 (15.0%)	280 (14.8%)	
5-7 days	1786 (18.8%)	1463 (19.2%)	323 (17.1%)	
Nap, mean (SD)	31.1 (42.2)	31.5 (42.6)	29.4 (40.8)	0.05
Age, mean (SD)	57.7 (9.4)	57.6 (9.0)	57.9 (10.4)	0.06
Sex				0.06
Male	5287 (49.9%)	3750 (49.0%)	1537 (52.1%)	
Smoking				<0.01
Never	6269 (62.1%)	4552 (59.5%)	1717 (70.5%)	
Ever	753 (7.5%)	607 (7.9%)	146 (6.0%)	
Current	3067 (30.4%)	2496 (32.6%)	571 (23.5%)	
Drinking				0.08
No	6882 (65.0%)	5025 (65.6%)	1857 (63.5%)	
Less than once a month	912 (8.6%)	659 (8.6%)	253 (8.6%)	
More than once a month	2786 (26.3%)	1971 (25.7%)	815 (27.9%)	
Medical insurance				<0.01
Yes	9816 (93.3%)	7153 (93.7%)	2663 (92.2%)	
BMI, mean (SD)	22.8 (3.6)	22.8 (3.6)	21.9 (4.7)	<0.01
Hukou				<0.01
Non-agriculture	8392 (79.2%)	6331 (82.7%)	2061 (69.9%)	
Agriculture	2144 (20.2%)	1282 (16.7%)	862 (29.3%)	

Others	65 (0.6%)	41 (0.5%)	24 (0.8%)	
Marital status				<0.05
Never married or divorced	185 (1.7%)	118 (1.5%)	67 (2.3%)	
Married	10419 (98.3%)	7537 (98.5%)	2882 (97.7%)	
Highest education level				<0.01
Illiterate	2684 (25.3%)	1957 (25.6%)	727 (24.8%)	
Primary	4141 (39.1%)	3137 (41.0%)	1004 (34.2%)	
Middle/high/vocational school	3510 (33.1%)	2430 (31.8%)	1080 (36.8%)	
College or higher	255 (2.4%)	129 (1.7%)	126 (4.3%)	
Diabetes				<0.05
Yes	362 (3.4%)	281 (3.7%)	81 (2.8%)	
Dyslipidemia				0.56
Yes	539 (5.2%)	383 (5.1%)	156 (5.4%)	

3.3 Incidence Rate of Hypertension and Kaplan-Meier Survival Estimates

As shown in Table 3, the mean follow-up time of the total population was 41.5 months. The mean follows up time for those who slept for <6, 6-7, 7-8, 8-9 were 41.3, 41.4, 41.3, 41.7, and 42.0 months, respectively. There was no significant difference. The distribution of survival time was shown in Appendix A.

The incidence rate in the whole sample was 58.2/10000 person-years. The incidence rate was 61.9/10000 person-years in males and 54.7/10000 person-years in females. The incidence rate was in 48.3/10000 person-years in middle-aged participants and 75.6/10000 person-years in older participants.

The Kaplan-Meier plot was shown in Figure 1 and there was no significant difference.

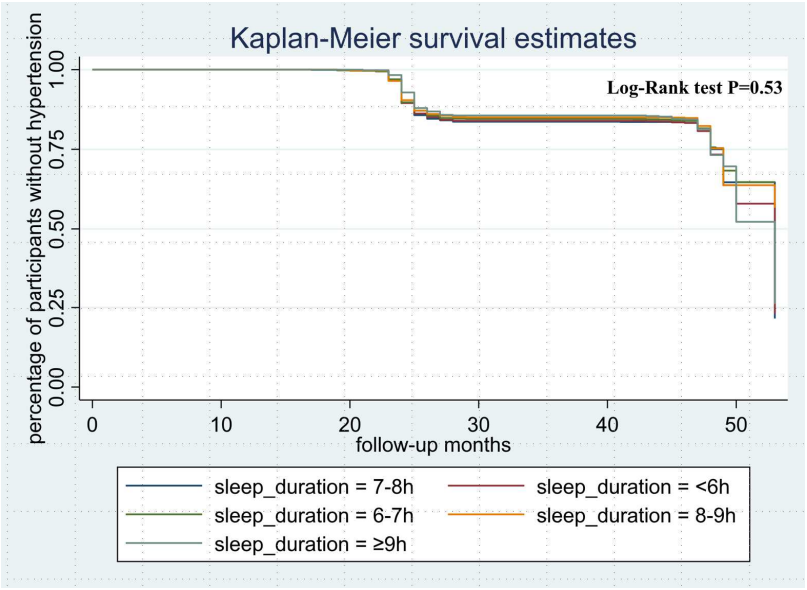


Figure 1: Kaplan-Meier survival estimates.

Table 3: Follow up time and incidence rate stratified by sex and age.

		Sleep duration					
	Total	<6	6-7	7-8	8-9	≥9	P-value
Follow up time, month (SD)	41.5 (12.2)	41.3 (12.3)	41.4 (12.4)	41.3 (12.1)	41.7 (12.0)	42.0 (11.7)	0.61
Incidence rate (95% CI)							
All (/10000 person-years)	58.2 (55.6-60.9)	61.0 (56.1-66.3)	55.6 (50.2-61.5)	58.4 (52.7-64.6)	56.9 (51.5-62.8)	58.3 (49.7-68.5)	
Sex (/10000 person-years)							
Male	61.9 (58.0-65.9)	60.1 (53.1-68.1)	62.2 (54.3-71.3)	60.4 (52.5-69.5)	63.1 (55.4-72.0)	66.7 (53.8-82.7)	
Female	54.7 (51.2-58.4)	61.7 (55.2-69.1)	49.2 (42.4-57.3)	56.3 (48.6-65.2)	50.1 (43.0-58.2)	50.9 (40.0-64.6)	
Age (/10000 person-years)							
≥45 and <60 years	48.3 (45.3-51.4)	49.7 (43.9-56.2)	49.4 (43.2-56.4)	46.7 (40.8-53.4)	48.6 (42.7-55.4)	44.4 (35.3-55.8)	
≥60 years	75.6 (70.7-80.8)	75.9 (67.7-85.1)	66.6 (57.1-77.6)	85.8 (73.7-100.0)	73.0 (62.9-84.8)	83.2 (66.5-104.0)	

3.4 Association between Sleep Duration and Hypertension in the Whole Sample

Table 4 shows the results of Cox proportional hazard models assessing the risk of hypertension onset during the follow-up survey according to the sleep duration at baseline in the whole sample.

Among all participants, in models 1, 2, 3, and 4, the result shows that there was an increased hazard of hypertension among participants who slept less than 7 hours and those with a sleep duration of 8-9 hours than the reference group. Nevertheless, no significant relationship was found.

In the interaction analysis between sex and sleep duration, no significant result was found, while between sex and sleep duration, a significant result (HR=1.370, 95% CI 1.076-1.745) more than 1 was reported in the group of <6 hours, which shows that there was an age difference in the association between sleep duration and hypertension.

Table 4: Association between sleep duration and the risk of hypertension in the whole sample.

	Sleep duration category (hours/night)				
HR (95% CI)	<6	6-7	7-8	8-9	≥9
Model 1	1.076 (0.897-1.292)	1.048 (0.867-1.268)	1.000	1.047 (0.868-1.264)	0.946 (0.725-1.235)
Model 2	1.120 (0.921-1.363)	1.055 (0.871-1.277)	1.000	1.028 (0.850-1.242)	0.943 (0.722-1.231)
Model 3	1.092 (0.898-1.329)	1.054 (0.870-1.276)	1.000	1.028 (0.850-1.243)	0.948 (0.726-1.238)
Model 4	1.112 (0.910-1.359)	1.048 (0.862-1.278)	1.000	1.053 (0.868-1.278)	0.956 (.0729-1.254)
Model 5					
Sleep duration	0.939 (0.770-1.145)	0.967 (0.793-1.181)	1.000	0.987 (0.812-1.201)	0.954 (0.732-1.242)
Sex&sleep duration	1.218 (0.843-1.761)	0.934 (0.634-1.376)	1.065 (0.724-1.567)	0.958 (0.652-1.407)	1.000 (omitted)
Model 6					
Sleep duration	1.101 (0.908-1.336)	1.044 (0.859-1.269)	1.000	1.052 (0.868-1.275)	0.953 (0.728-1.249)
Age&sleep duration	1.370 (1.076-1.745)*	1.108 (0.897-1.367)	0.992 (0.776-1.267)	1.055 (0.827-1.346)	1.263 (0.885-1.803)

3.5 Association between Sleep Duration and Hypertension Stratified by Age

The results of Cox proportional hazard models assessing the risk of hypertension onset during the follow-up survey among participants stratified by age combined were shown in Table 5.

In the middle-aged group, all four models showed that there was no significant result. However, in the older group, all the four models reported lower HRs than reference group for those with sleep duration 6-7 hours (Model 1: HR=0.768, 95% CI 0.619-0.954; Model 2: 0.780, 95% CI 0.626-0.972; Model 3: 0.772, 95% CI 0.619-0.962; Model 4: 0.758, 95% CI 0.606-0.948).

Table 5: Association between sleep duration and the risk of hypertension stratified by age.

HR (95% CI)	Sleep duration category (hours/night)				
	<6	6-7	7-8	8-9	≥9
≥45 and <60 years					
Model 1	1.076 (0.897-1.292)	1.048 (0.867-1.268)	1.000	1.047 (0.868-1.264)	0.946 (0.725-1.235)
Model 2	1.120 (0.921-1.363)	1.055 (0.871-1.277)	1.000	1.028 (0.850-1.242)	0.943 (0.722-1.231)
Model 3	1.092 (0.898-1.329)	1.054 (0.870-1.276)	1.000	1.028 (0.850-1.243)	0.948 (0.726-1.238)
Model 4	1.112 (0.910-1.359)	1.048 (0.862--1.274)	1.000	1.053 (0.868-1.278)	0.956 (0.729-1.254)
≥60 years					
Model 1	0.878 (0.725-1.063)	0.768 (0.619-0.954)*	1.000	0.861 (0.695-1.066)	0.951 (0.725-1.246)
Model 2	0.911 (0.740-1.122)	0.780 (0.626-0.972)*	1.000	0.878 (0.709-1.089)	0.954 (0.726-1.253)
Model 3	0.890 (0.722-1.096)	0.772 (0.619-0.962)*	1.000	0.859 (0.693-1.065)	0.906 (0.688-1.192)
Model 4	0.875 (0.708-1.081)	0.758 (0.606-0.948)*	1.000	0.825 (0.663-1.026)	0.880 (0.665-1.162)

4. Discussion

4.1 Main Findings

The longitudinal study of Chinese middle-aged and older adults without hypertension examined the relationship between night sleep duration and incident hypertension. Although no significant relationship was found among the whole sample, this study revealed the existence of age difference in the association between sleep and hypertension. The age-specific analysis showed that sleep for 6-7 hours could lower the incidence of hypertension among older adults, compared with sleep duration of 7-8 hours, while no significant relationship was found in middle-aged adults. Additionally, we found that extreme sleep duration (<6 hours or ≥9 hours), did not significantly increase the incidence of hypertension in all participants, middle-aged participants, and older participants.

4.2 Sleep Duration and Hypertension among Middle-aged and Older Adults

The present study found that among middle-aged and older adults, there was no significant relationship between sleep duration and hypertension, which was inconsistent with some previous studies.

Many previous longitudinal studies showed increased hazards of short and long sleep duration compared with among adults (Feng et al., 2019; Gangwisch James E. et al., 2006). A cross-sectional study included participants from CHARLS in 2011, which

was similar to the present study, also found that short sleep duration (<6 hours) was a risk factor of hypertension for middle-aged and older Chinese adults (Guo et al., 2016).

Nevertheless, some studies also reported negative results between sleep duration and hypertension. Lopez-Garcia (2009) conducted a prospective study in the older Spanish population and found that there was no significant association between short and long sleep duration and incident hypertension.

Overall, although the results among middle-aged and older adults were controversial, most of the studies reported significant results. The present study conducted a longitudinal study in 8850 adults aged 45 years or above based on CHARLS sample, which was a representative sample of Chinese adults, found a negative result. Nevertheless, when compared with the results of previous studies, some differences in methods were noticeable. Firstly, the classification of self-reported sleep duration was diverse. Some studies used a questionnaire that only required integers of sleep duration from interviewees, such as CHNS. Moreover, some studies applied a different definition of short sleep duration and long sleep duration and different sleep duration as reference. For example, Fang (2012) defined short sleep duration as <7 hours while the classification in Guo's (2016) study was <6 hours. Sometimes even the same cut points, such as <7 hours and ≤7 hours, were not comparable, because the cut points could account for a considerable percentage since participants tended to reported integers as sleep duration. Secondly, Although Guo's (2016) study also enrolled participants from CHARLS, it did not conduct a longitudinal analysis to examine the causality between

extreme sleep duration and hypertension. The present study enrolled not only wave 1 in 2011 but also wave 2 and 3 and contributed to the investigation of causality between extreme sleep duration and hypertension, which filled the research gap of previous cross-sectional CHARLS study. Thirdly, when compared with other longitudinal studies, the present study included a shorter time of follow-up, which might not observe sufficient incident hypertension. Feng's (2019) study followed up for seven years and Gangwisch (2006) enrolled participants from 1982 to 1992 follow-up studies of the NHANES, while the present study only included participants from 2011 to 2015 because no data of blood pressure measurements have been released from CHARLS. The limitation of follow-up time might weaken the generality of the results under the long-term circumstance.

4.3 Age and Sex Differences

The present study found that although there was no sex difference in the association between sleep duration and hypertension, the age-specific analysis showed that 6-7 hours of sleep duration seemed to be a protective factor for adults aged 60 or above when compared with 7-8 hours of sleep duration.

The result was similar to some previous cross-sectional studies, which found that younger people were easier to develop hypertension compared with older people (Grandner Michael et al., n.d.; Kim & Jo, 2010). There were some possible explanations for the age difference. Firstly, older adults might have more time to take nap since they

have retired. Secondly, older adults who had no hypertension at baseline might have better lifestyles or protective genes since they have more time to develop hypertension compared with middle-aged adults.

National Sleep Foundation conducted a systematic literature review, which explored the sleep duration data and the effect and consequences of prolonged and reduced sleep duration and released a sleep duration recommendation stratified by age groups in 2015 (Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, Hazen, Herman, Katz, et al., 2015). According to the report, sleep duration was categorized into the recommended, (might be) appropriate, and not recommended sleep duration. 7-9 hours is the recommended sleep duration and 6/10 hours might be appropriate for adults aged 26-64 years. 7-8 hours is the recommended and 5-6 hours or 9 hours might be appropriate for adults aged 65 years or above. According to the present study, 6-7 hours might be the most appropriate sleep duration for older adults when only considering the risk of hypertension. The series of epidemiological evidence need be taken into consideration when developing updating sleep duration recommendation.

5. Conclusions

5.1 Conclusions and Implications

Based on data from CHARLS in 2011, 2013, and 2015, this study explored the relationship between sleep duration and risk of hypertension and the effect of sex and age on the association between sleep duration and hypertension. Based on the results and discussion, the conclusions can be drawn as follows.

Firstly, there was no significant association between sleep duration and hypertension among the Chinese population aged 45 years or above.

Secondly, no significant association was found between sleep duration and risk of hypertension among middle-aged adults and older adults. However, 6-7 hours of sleep duration is a protective factor for older adults, compared with a sleep duration of 7-8 hours.

Our findings suggest that 6-7 hours of sleep duration should be recognized as a protective factor for the blood pressure of older adults. When developing sleep duration recommendations for the Chinese population, the epidemiological evidence should be taken into consideration.

5.2 Strengths and Limitations

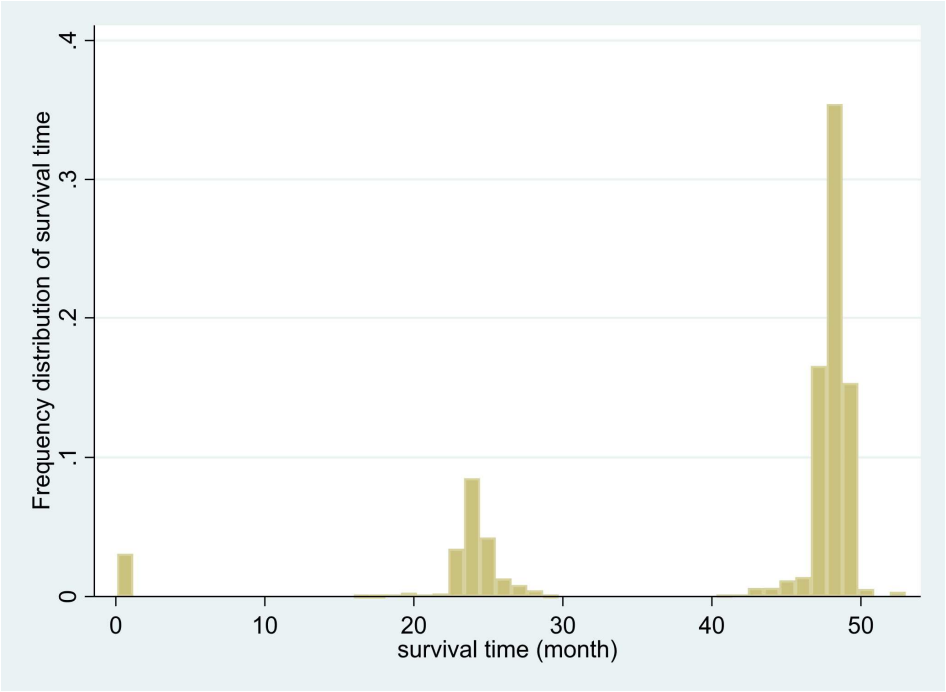
The strength of the present study lies in its large representative sample of the Chinese population and the design of the longitudinal study. As one of the few

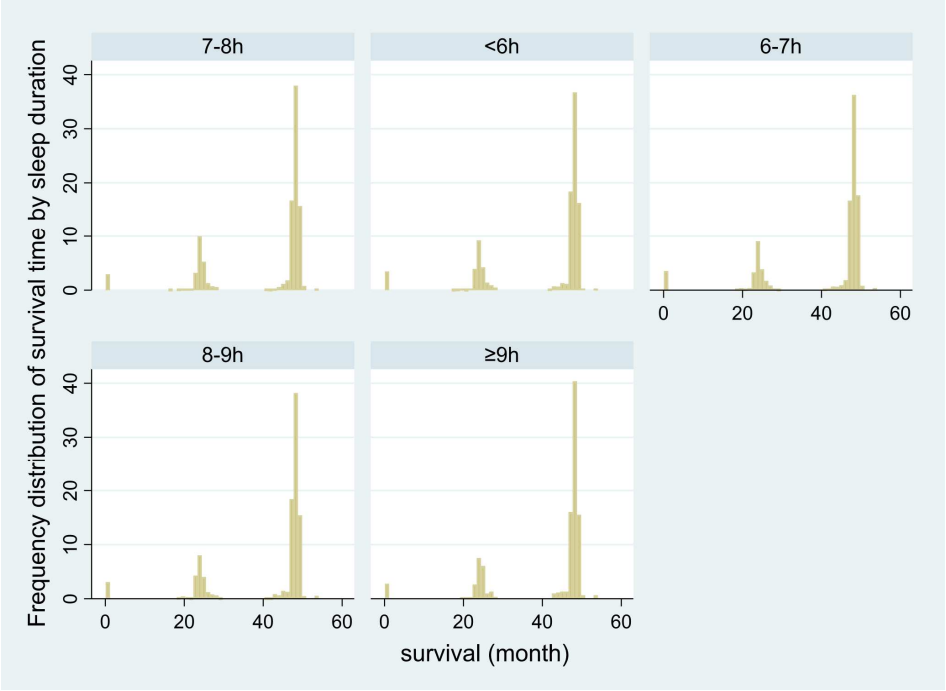
longitudinal studies to investigate the effect of sleep duration, the study focused on the middle-aged and older Chinese population, which filled the research gap.

Several limitations of the present study should be discussed. Firstly, the data of sleep duration were self-reported. Lauderdale (2008) explored the association between objectively measured sleep duration and self-reported or subjectively measured sleep duration in US middle-aged adults and found that the mean of the former was almost one hour greater than the latter. Therefore, the results of the present study should be interpreted with caution. Secondly, the definition of survival time might not be accurate. The timing of onset of hypertension was defined as the timing of follow-up, which was later than the event. Therefore, the method of calculating survival time might overestimate the survival time and then underestimate the incidence rate. Thirdly, the study only used the sleep duration in the baseline survey. It is possible that there were participants who changed sleep duration in the following waves. In this situation, the endpoint of one single participant was generated from the impact of different sleep duration, which should be analyzed in a more complicated model. Fourthly, previous epidemiological evidence shows that physical activity was associated with hypertension, but the study did not include physical activity in the adjusted model. The reason was that physical activity was only reported in a small proportion of selected samples but not in the whole sample. Fifthly, the study only included follow-up surveys in 2013 and 2015, which contributed to a follow-up time of about 4 years. The time might not be sufficient for some people to develop hypertension. To better understand the association

between sleep duration and hypertension, it is recommended to include more waves and consider the change of sleep duration in follow-up waves in the future.

Appendix A


Frequency distribution of survival time
0
.1
.2
.3
.4
0
10
20
30
40
50
survival time (month)


Frequency distribution of survival time by sleep duration
7-8h
<6h
6-7h
8-9h
≥9h
0
10
20
30
40
0
20
40
60
survival (month)

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