

# BMJ Open Relationship between sleep duration and hypertension in northeast China: a cross-sectional study

Meng Li,<sup>1</sup> Shoumeng Yan,<sup>1</sup> Shan Jiang,<sup>1</sup> Xiaoyu Ma,<sup>1</sup> Tianyu Gao,<sup>1,2</sup> Bo Li<sup>1</sup>

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## ABSTRACT

**Objectives** Previous studies have reported that sleep duration might increase the risk of hypertension. However, the results have been conflicting. We investigated whether sleep duration is independently associated with hypertension. We aimed to assess the relationship between sleep duration and hypertension in a population-based cross-sectional study.

**Methods** In this study we used multistage stratified cluster sampling. A total of 19 407 adults aged 18–79 years were enrolled in the study. The participants were divided into three groups (<7 hours/day, 7–8 hours/day and >8 hours/day) according to self-reported sleep duration. Hypertension was defined as systolic blood pressure  $\geq 140$  mm Hg or diastolic blood pressure  $\geq 90$  mm Hg or the use of anti-hypertensive medications. Univariate and multivariate logistic regressions were performed to determine the association between hypertension and sleep duration adjusted for sociodemographic, body mass index, and lifestyle covariates.

**Results** The overall prevalence of hypertension was 32.6%. Among participants aged 18–44 years, individuals sleeping less than 7 hours per day had a higher risk of hypertension (OR=1.24, 95% CI: 1.05 to 1.46), compared with those who slept 7–8 hours per day. There were no significant associations between sleep duration and hypertension in the total sample, among middle-aged adults (45–59 years) or older adults (60–79 years).

**Conclusions** Our study demonstrates that short sleep duration was significantly associated with hypertension among people aged 18–44 years in northeast China.

## Strengths and limitations of this study

- A multistage, stratified random cluster sampling design was used to obtain a large, representative sample of the Jilin population.
- There were excellent response rates to sleep duration questions and hypertension questions and measurements.
- A broad range of covariates were controlled in the analysis, including age, sex, education, marital status, income, occupation, body mass index, drinking, smoking, salt intake and exercise.
- The limitation of this study is that the sleep duration obtained from the questionnaire was subjective and may differ from precisely measured sleep duration.

The latest data from the Global Burden of Disease Study in 2015 showed that high SBP continues to be the largest contributor to global disability-adjusted life-years (DALYs), causing 211.8 million global DALYs each year.<sup>6</sup> According to a previous study,<sup>7</sup> hypertension is a major risk factor for cardiovascular disease (CVD), heart attack, heart failure, stroke and kidney disease. Studies have shown that sleep duration is associated with hypertension.<sup>8–9</sup> Short sleep duration, usually defined as less than 7 hours, 6 hours or 5 hours per night,<sup>10</sup> was associated with an increased risk of prevalent hypertension.<sup>11–12</sup> The relationship between self-reported sleep duration and hypertension was first reported as a U-shaped association in the Sleep Heart Health Study (SHHS).<sup>13</sup> In the study, Gottlieb *et al* found that sleep duration of less than 7 hours per night or more than 8 hours per night was associated with an increased prevalence of hypertension. The results from the NHANES also demonstrated an association between sleep duration of less than 5 hours per night and an increased risk of hypertension in the same year.<sup>14</sup> However, there are conflicting results. A community-based 7-site study<sup>15</sup> came to the conclusion that sleep duration was unrelated to blood pressure cross-sectionally or longitudinally in midlife

## INTRODUCTION

In many countries, the diagnosis of hypertension is based on a systolic blood pressure (SBP) of at least 140 mm Hg, a diastolic blood pressure (DBP) of at least 90 mm Hg or both.<sup>1,2</sup> In 2000, the overall prevalence of hypertension was 26.4% worldwide.<sup>3</sup> In 2010, hypertension was the leading single contributor to global mortality, being responsible for more than 9 million deaths.<sup>4</sup> Data from the National Health and Nutrition Examination Survey (NHANES) in 2011–2012 estimated the overall prevalence of hypertension among US adults aged 18 and over was 29.1% (29.7% men and 28.5% women).<sup>5</sup>



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<sup>1</sup>Department of Epidemiology and Biostatistics, Jilin University School of Public Health, Changchun, China

<sup>2</sup>Department of Medical Health Inspection, Changchun Health Supervision Institute, Changchun, China

### Correspondence to

Professor Bo Li;  
li\_bo@jlu.edu.cn

women. Similarly, a study among non-insomniac elderly subjects<sup>16</sup> indicated that sleep duration was not associated with the prevalence of hypertension. Therefore, the relationship between sleep duration and hypertension needs to be further investigated.

In this study, we investigated the relationship between self-reported sleep duration and hypertension among subjects who participated in a representative population-based survey from the Jilin province in northeast China. Moreover, the role of age and sex in the relationship between sleep duration and hypertension was also evaluated.

## METHODS

### Study design and population

This study was embedded in the Jilin Provincial Chronic Disease Survey, a population-based cross-sectional study conducted from June 2012 to August 2012. A multi-stage, stratified, cluster sampling method was used to select a representative sample of community-dwelling residents who had lived in nine regions of Jilin Province (Changchun, Jilin, Siping, Liaoyuan, Tonghua, Baishan, Songyuan, Baicheng and Yanbian) for at least 6 months. The detailed stratifying process was reported previously.<sup>17</sup> A total of 23 050 individuals were recruited and 21 435 of them completed the survey (84.9% response rate). In this study, 2028 subjects were excluded from the statistical analyses due to missing data on marital status, occupation, income, height, weight, SBP or DBP, yielding a final sample size of 19 407 subjects. Among the 2028 excluded subjects (1218 men and 809 women), the mean age was 47.07 years (SD 13.40, range 18–79 years).

We adhered to the bioethics principles of the Declaration of Helsinki.

### Definition of major variables

After at least 5 min of rest, two blood pressure measurements were made with the participants in a seated position, using appropriately sized cuffs and calibrated electronic sphygmomanometers (OMRON-HEM-7200, Omron, Kyoto, Japan). The mean of the two blood pressure measurements taken at 2 min intervals was used in the analyses. In our study, hypertension was defined as SBP  $\geq 140$  mm Hg or DBP  $\geq 90$  mm Hg or the current use of anti-hypertensive medication.

Self-reported sleep duration was assessed by the following question: 'On average, how many hours of actual sleep did you get each day (24 hours) during the past month?' The results were categorised into three groups for analysis: <7 hours/day, 7–8 hours/day and  $\geq 8$  hours/day, and we chose the category of 7–8 hours/day as the reference group in accordance with a previous study.<sup>13</sup>

A structured questionnaire was used to collect socio-demographic information of the participants, and the measured characteristics included gender (male, female), age (18–44, 45–59, 60–79 years), education

(elementary, junior, senior, university), marital status (married, unmarried, separated/divorced, widowed), occupation (manual labour, mental labour, unemployed, retired) and family monthly income per capita (<1000, 1000–3000, >3000 RMB). The BMI was measured, calculated as weight (kg)/height squared ( $\text{kg}/\text{m}^2$ ). Participants were categorised as underweight (BMI <18.5  $\text{kg}/\text{m}^2$ ), normal weight (BMI=18.5 to 25  $\text{kg}/\text{m}^2$ ), overweight (BMI=25.0 to 30.0  $\text{kg}/\text{m}^2$ ) or obese (BMI >30.0  $\text{kg}/\text{m}^2$ ).<sup>18</sup> Other variables, including smoking status (yes, no, former), drinking (yes, no), salt intake (high salt, light, moderate) and physical exercise (frequently, occasionally, never) were assessed. A smoker was defined as a person who had smoked at least one cigarette a day over the past 30 days; a former smoker was defined as a person who had smoked more than 100 cigarettes cumulatively, but had quit smoking or had not reached the current smoking level at the time of the survey; participants who reported never having smoked 100 cigarettes were defined as never-smokers. A drinker was defined as a person who consumed an average of more than one alcoholic drink per week. Based on self-reported results, we divided the salt intake into three categories: high salt, light and moderate. Participants who exercised more than three times a week were defined as 'exercise frequently'; those who exercised one or two times a week were defined as 'exercise occasionally'; and those who usually exercised less than once a week were defined as 'never exercise'.

### Statistical analysis

Data were analysed using SPSS software (V. 24.0, IBM).  $\chi^2$  tests were used to test the association between hypertension and categorical, potentially confounding variables. A p value of less than 0.05 was considered statistically significant. After preliminary univariate analyses, we used logistic regression models to examine the effect of sleep duration on the risk of hypertension, and the OR and 95% CIs were calculated. Four regression models were generated. The first model (model 1) was generated without adjusting for any covariates. Covariates in the first adjusted multivariate model (model 2) included age, gender, education, marital status, occupation and family per capita monthly income. Model 3 adjusted for factors in model 2 plus BMI. Finally, model 4 was further adjusted for smoking, drinking, salt intake and physical exercise. The dependent variable was the presence of hypertension. In addition, we performed subgroup analysis stratified by age and sex.

### Patient and public involvement

No patients were involved in the design of this study, the specific aims or the research questions, nor were they involved in the recruitment and conduct of the study. No patients were involved in the interpretation of study results or write-up of the manuscript. There are no plans to disseminate the results of the research to study participants.

**Table 1** Characteristics of the three groups stratified according to sleep duration

Characteristic	Group	Sleep duration (%)			$\chi^2$	P value
		<7 hours/day	7–8 hours/day	>8 hours/day		
Numbers of subjects		7106 (36.6)	4964 (25.6)	7337 (37.8)		
Sex	Male	3364 (36.9)	2406 (26.4)	3348 (36.7)	10.143	0.006
	Female	3742 (36.4)	2558 (24.9)	3989 (38.7)		
Age	18–44	2100 (26.5)	2148 (27.1)	3683 (46.4)	660.611	<0.001
	45–59	3295 (42.9)	1940 (25.3)	2440 (31.8)		
	60–79	1711 (45.0)	876 (23.1)	1214 (31.9)		
Education	Elementary	2316 (40.0)	1362 (23.5)	2111 (36.5)	109.944	<0.001
	Junior	1999 (35.7)	1447 (25.8)	2154 (38.5)		
	Senior	1887 (38.1)	1232 (24.9)	1833 (37.0)		
	University	904 (29.5)	923 (30.1)	1239 (40.4)		
Marital status	Married	6101 (36.4)	4321 (25.7)	6360 (37.9)	184.756	<0.001
	Unmarried	343 (25.9)	366 (27.7)	613 (46.4)		
	Separated/divorced	180 (49.8)	75 (20.8)	106 (29.4)		
	Widowed	482 (51.2)	202 (21.4)	258 (27.4)		
Occupation	Manual labour	3241 (35.4)	2294 (25.1)	3622 (39.5)	172.040	<0.001
	Mental labour	2071 (33.5)	1653 (26.7)	2461 (39.8)		
	Unemployed	741 (40.9)	450 (24.9)	618 (34.2)		
	Retired	1053 (46.7)	567 (25.1)	636 (28.2)		
Income (RMB)	<1000	3032 (38.2)	1927 (24.2)	2990 (37.6)	29.632	<0.001
	1000–3000	3452 (36.2)	2503 (26.3)	3570 (37.5)		
	>3000	622 (32.2)	534 (27.6)	777 (40.2)		
Smoking	Never	4094 (34.5)	3061 (25.8)	4717 (39.7)	69.354	<0.001
	Yes	2375 (39.8)	1503 (25.2)	2092 (35.0)		
	Ever	637 (40.7)	400 (25.6)	528 (33.7)		
Drinking	No	4786 (35.9)	3391 (25.4)	5163 (38.7)	15.863	<0.001
	Yes	2320 (38.3)	1573 (25.9)	2174 (35.8)		
Salt intake	Moderate	2283 (34.0)	1767 (26.3)	2670 (39.7)	31.938	<0.001
	High salt	2777 (37.9)	1856 (25.3)	2699 (36.8)		
	Light	2046 (38.2)	1341 (25.0)	1968 (36.8)		
Physical exercise	Never	3326 (36.7)	2249 (24.9)	3477 (38.4)	112.339	<0.001
	Frequently	2342 (40.4)	1522 (26.2)	1936 (33.4)		
	Occasionally	1438 (31.6)	1193 (26.2)	1924 (42.2)		
Body mass index (BMI)	Normal weight	3915 (35.8)	2797 (25.6)	4223 (38.6)	39.105	<0.001
	Underweight	260 (30.7)	205 (24.2)	381 (45.1)		
	Overweight	2462 (38.5)	1648 (25.8)	2286 (35.7)		
	Obese	469 (38.2)	314 (25.5)	447 (36.3)		

## RESULTS

The baseline characteristics of the study population according to sleep duration levels are presented in [table 1](#). Of the 19 407 participants in our study (53.0% women; mean age: 47.53 years; SD: 13.13 years; range: 18–79 years), the median reported sleep duration of the study population was 7 hours per day, 36.6% of the subjects

reported a sleep duration of less than 7 hours per day, and an average sleep duration of 8 or more hours per day was reported by 37.8% of the study population. Significant differences were observed between sleep duration and sex, age, education, marital status, occupation, income, smoking, drinking, salt intake, exercise and BMI. Subjects with short sleep durations were slightly older, heavier and

had a lower level of education than subjects sleeping 7 to 8 hours per day (table 1). They were also more likely to be men, smokers, drinkers and have a high

salt diet. Individuals with more hours of sleep per night were younger and more likely to be non-smokers and non-drinkers.

**Table 2** Baseline characteristics of the participants stratified by hypertension

Characteristic	Group	Hypertension Number of subjects (%)		$\chi^2$	P value	OR	95% CI
		No	Yes				
Number of subjects		13087 (67.4)	6320 (32.6)				
Sex	Male	5742 (63.0)	3376 (37.0)	155.787	<0.001	1.000	–
	Female	7345 (71.4)	2944 (28.6)			0.682	(0.642 to 0.724)
Age	18–44	6608 (83.3)	1323 (16.7)	1181.906	<0.001	1.000	–
	45–59	4722 (61.5)	2953 (38.5)			3.124	(2.898 to 3.366)
	60–79	1757 (46.2)	2044 (53.8)			5.811	(5.327 to 6.338)
Education	Elementary	3509 (60.6)	2280 (39.4)	282.324	<0.001	1.000	–
	Junior	3779 (67.5)	1821 (32.5)			0.742	(0.687 to 0.801)
	Senior	3408 (68.8)	1544 (31.2)			0.697	(0.644 to 0.755)
	University	2391 (78.0)	675 (22.0)			0.434	(0.393 to 0.480)
Marital status	Married	11201 (66.7)	5581 (33.3)	366.705	<0.001	1.000	–
	Unmarried	1157 (87.5)	165 (12.5)			0.286	(0.242 to 0.338)
	Separated/divorced	251 (69.5)	110 (30.5)			0.880	(0.701 to 1.103)
	Widowed	478 (50.7)	464 (49.3)			1.948	(1.708 to 2.222)
Occupation	Manual labour	6159 (67.3)	2988 (32.7)	417.761	<0.001	1.000	–
	Mental labour	4634 (74.9)	1551 (25.1)			0.688	(0.640 to 0.739)
	Unemployed	1107 (61.2)	702 (38.8)			1.303	(1.174 to 1.446)
	Retired	1187 (52.6)	1069 (47.4)			1.850	(1.685 to 2.031)
Income (RMB)	<1000	5026 (63.2)	2923 (36.8)	118.706	<0.001	1.000	–
	1000–3000	6641 (69.7)	2884 (30.3)			0.747	(0.701 to 0.795)
	>3000	1420 (73.5)	513 (26.5)			0.621	(0.556 to 0.694)
Smoking	Never	8293 (69.9)	3579 (30.1)	145.176	<0.001	1.000	–
	Yes	3930 (65.8)	2040 (34.2)			1.203	(1.126 to 1.285)
	Ever	864 (55.2)	701 (44.8)			1.880	(1.689 to 2.092)
Drinking	No	9306 (69.8)	4034 (30.2)	105.100	<0.001	1.000	–
	Yes	3781 (62.3)	2286 (37.7)			1.395	(1.309 to 1.487)
Salt intake	Moderate	4748 (70.7)	1972 (29.3)	50.369	<0.001	1.000	–
	High salt	4784 (65.2)	2548 (34.8)			1.282	(1.194 to 1.3777)
	Light	3555 (66.4)	1800 (33.6)			1.219	(1.128 to 1.317)
Physical exercise	Never	6298 (69.6)	2754 (30.4)	283.246	<0.001	1.000	–
	Frequently	3430 (59.1)	2370 (40.9)			1.580	(1.475 to 1.693)
	Occasionally	3359 (73.7)	1196 (26.3)			0.814	(0.752 to 0.882)
BMI	Normal weight	6727 (76.2)	2105 (23.8)	1063.588	<0.001	1.000	–
	Underweight	752 (88.9)	94 (11.1)			0.359	(0.288 to 0.446)
	Overweight	4211 (61.5)	2639 (38.5)			2.172	(2.034 to 2.318)
	Obese	1397 (48.5)	1482 (51.5)			3.142	(2.787 to 3.542)
Sleep duration	<7 hours/day	4480 (63.0)	2626 (37.0)	103.575	<0.001	1.000	–
	7–8 hours/day	3415 (68.8)	1549 (31.2)			1.292	(1.197 to 1.396)
	>8 hours/day	5192 (70.8)	2145 (29.2)			0.911	(0.842 to 0.985)



**Table 3** Logistic regression analyses of the relationship between hypertension and categorical sleep duration

Sleep duration	Model 1	Model 2	Model 3	Model 4
<b>Total</b>				
<7 hours/day	1.30 (1.20–1.40)	1.09 (1.01–1.18)	1.09 (1.01–1.18)	1.08 (0.99–1.17)
7–8 hours/day	1.00	1.00	1.00	1.00
≥8 hours/day	0.91 (0.84–0.99)	0.99 (0.91–1.07)	1.00 (0.92–1.09)	1.01 (0.92–1.10)
<b>Ages 18–44</b>				
<7 hours/day	1.38 (1.18–1.61)	1.35 (1.15–1.59)	1.27 (1.08–1.50)	1.24 (1.05–1.46)
7–8 hours/day	1.00	1.00	1.00	1.00
≥8 hours/day	0.89 (0.77–1.03)	0.95 (0.82–1.11)	0.98 (0.84–1.14)	0.99 (0.84–1.15)
<b>Ages 45–59</b>				
<7 hours/day	1.02 (0.91–1.15)	1.01 (0.90–1.14)	1.03 (0.91–1.16)	1.02 (0.91–1.15)
7–8 hours/day	1.00	1.00	1.00	1.00
≥8 hours/day	1.03 (0.91–1.17)	1.03 (0.91–1.17)	1.03 (0.91–1.17)	1.03 (0.91–1.17)
<b>Ages 60–79</b>				
<7 hours/day	1.02 (0.87–1.20)	1.02 (0.86–1.20)	1.03 (0.87–1.21)	1.02 (0.86–1.20)
7–8 hours/day	1.00	1.00	1.00	1.00
≥8 hours/day	1.06 (0.89–1.26)	1.07 (0.89–1.27)	1.06 (0.89–1.27)	1.06 (0.89–1.27)
<b>Male</b>				
<7 hours/day	1.24 (1.12–1.39)	1.08 (0.97–1.21)	1.08 (0.97–1.22)	1.06 (0.94–1.19)
7–8 hours/day	1.00	1.00	1.00	1.00
≥8 hours/day	1.00 (0.90–1.12)	1.02 (0.91–1.14)	1.03 (0.92–1.16)	1.04 (0.92–1.17)
<b>Female</b>				
<7 hours/day	1.36 (1.22–1.51)	1.08 (0.96–1.22)	1.09 (0.96–1.23)	1.09 (0.96–1.23)
7–8 hours/day	1.00	1.00	1.00	1.00
≥8 hours/day	0.84 (0.75–0.95)	1.01 (0.89–1.14)	1.01 (0.89–1.14)	1.01 (0.90–1.14)

Model 1: Unadjusted.

Model 2: Adjusted for age, sex, education, marital status, occupation, income.

Model 3: Adjusted for age, sex, education, marital status, occupation, income, BMI.

Model 4: Adjusted for age, sex, education, marital status, occupation, income, BMI, smoking, drinking, salt intake, physical exercise.

BMI, body mass index.

The characteristics of the study population stratified by hypertension are shown in [table 2](#). In our study, the overall prevalence of hypertension was 32.6% (37.0% men, 28.6% women). Hypertension was found to be associated with sex, age, education, marital status, occupation and family monthly income per capita. Additionally, hypertension was associated with smoking, drinking, salt intake, exercise and BMI. As shown in [table 2](#), there was significant difference between sleep duration and the prevalence of hypertension. Hypertensive subjects were more likely to sleep for shorter durations.

[Table 3](#) shows the results of multiple logistic regressions performed to test the association between hypertension and sleep duration adjusted for different potential confounders. For the total sample, participants who slept less than 7 hours per day were significantly more likely to be hypertensive (OR=1.30, 95% CI: 1.20 to 1.40, model 1). After adjusting for sociodemographic variables (OR=1.09, 95% CI: 1.00 to 1.18, model 2), sociodemographic variables and BMI (OR=1.09, 95% CI: 1.00 to 1.18, model 3),

a sleep duration of less than 7 hours per day continued to be associated with a higher risk of hypertension. However, the observed association between sleep duration and hypertension was attenuated after adjusting for sociodemographic variables and BMI. Then, after adjusting for sociodemographic variables, BMI, and lifestyle factors, a short sleep duration (<7 hours/day) was no longer associated with hypertension (OR=1.08, 95% CI: 0.99 to 1.17, model 4). Among longer sleepers who slept 8 or more hours per day, after adjusting for relevant confounders, we did not find an association between a longer sleep duration and hypertension (OR=0.99, 95% CI: 0.91 to 1.07, model 2; OR=1.00, 95% CI: 0.92 to 1.09, model 3; OR=1.01, 95% CI: 0.92 to 1.10, model 4).

The logistic regression analyses were repeated after stratifying by age (18–44, 45–59, 60–79 years). Subjects between the ages of 18 and 44 years who slept less than 7 hours per day were associated with a higher probability of hypertension after considering different covariates (OR=1.38, 95% CI: 1.18 to 1.61, model 1; OR=1.35,

95% CI: 1.15–1.59, model 2; OR=1.27, 95% CI: 1.08 to 1.50, model 3; OR=1.24, 95% CI: 1.05 to 1.46, model 4). However, all four models failed to show any significant associations between sleep duration and hypertension either among subjects between the ages of 45–59 years or among subjects between the ages of 60–79 years.

Repeating the analysis for men and women separately, we found that the unadjusted results were similar between men and women. Subjects who reported sleeping less than 7 hours per day were significantly more likely to be hypertensive than subjects who reported getting 7 to less than 8 hours of sleep per day (men: OR=1.24, 95% CI: 1.12 to 1.39, model 1; women: OR=1.36, 95% CI=1.22–1.51, model 1). When sociodemographic variables, BMI and lifestyle factors were included in the models, sleep duration was not associated with the risk of hypertension in either male or female subjects.

## DISCUSSION

This present study described an analysis of data, collected from the Jilin Provincial Chronic Disease Survey, that investigates the relationship between sleep duration and hypertension. In this cross-sectional study, we observed an association between short sleep durations (<7 hours/day) and an increased risk of hypertension in young adults (18–44 years). This association was attenuated by the inclusion in the multivariate models of sociodemographic covariates—BMI and lifestyle factors. Compared with the young adults, an association between short sleep duration and hypertension was not found for middle-aged participants (45–59 years), old participants (60–79 years) or the total sample. Furthermore, no association between sleep duration and hypertension was found when male or female participants were analysed separately.

There have been several studies<sup>19–23</sup> focusing on the relationship between sleep duration and blood pressure. However, this relationship is still controversial. Recent reviews<sup>10 24 25</sup> and meta-analyses<sup>26 27</sup> have further clarified the association between short sleep durations and hypertension risk. Two adult meta-analyses<sup>11 12</sup> showed similar results, indicating that short sleep durations were associated with an increased risk of hypertension (OR=1.20, 95% CI: 1.09 to 1.32,  $p<0.001$ ; OR=1.21, 95% CI: 1.09 to 1.34,  $p<0.001$ ). A meta-analysis<sup>26</sup> based on 17 cohort studies demonstrated that short sleep durations increased the risk of hypertension incidence (OR=1.21, 95% CI: 1.05 to 1.40). In fact, the relationship between hypertension and sleep duration may vary by age. In 2008, a Korean study found that short sleep durations were associated with hypertension prevalence only in those aged less than 60 years.<sup>28</sup> This was consistent with a Spanish study, which demonstrated that self-reported sleep duration was not associated with hypertension in older adults.<sup>29</sup> In our study, short sleep duration was associated with a higher risk of hypertension in younger adults but not in middle-aged or elderly individuals. Changes in sleep quality and quantity in later life may be related to

this age-dependent association.<sup>30</sup> Furthermore, participants experiencing hypertension are probably less likely to survive into their later years. In the cross-sectional and prospective analyses of the Whitehall II Study,<sup>31</sup> short duration of sleep (<5 hours/night) was associated with increased risk of hypertension among women when compared with the median sleep duration of 7 hours. The result of the Whitehall II Study showed a gender-specific association between short sleep duration and prevalent and incident hypertension. However, in our findings, no association between sleep duration and hypertension was observed in men or women after taking into account potential confounders. Two factors may explain the differential association of short sleep duration and hypertension in the male and female groups. First, hormonal influences may play an important role, especially during the premenopausal period.<sup>32</sup> Second, the SHHS indicated that male and female participants answer questions on sleep differently.<sup>33</sup> Therefore, the differential self-reporting of sleep habits of male and female participants may have an impact on these gender-specific associations.

In addition to short sleep duration, sleep disorders such as sleep insomnia,<sup>34 35</sup> obstructive sleep apnea<sup>36</sup> and other sleep quality problems<sup>37–39</sup> have also been shown to be risk factors for hypertension. Sherwood *et al*<sup>40</sup> reported that poor sleep quality was associated with non-dipping blood pressure and the potential mechanism might be heightened sympathetic activity. Thomas *et al*<sup>41</sup> proposed other potential mechanisms including activation of the hypothalamic–pituitary–adrenal axis and the stress-diathesis model. Unfortunately, sleep quality or related issues were not recorded in our study, and we will try to take sleep quality into account in our future investigations.

The biological mechanisms underlying the association of short sleep duration with hypertension are complex and not fully understood. Early data indicated a lower level of sympathetic-nerve activity and blood pressure during deep non-rapid-eye-movement (REM) sleep.<sup>42</sup> During REM sleep, there is an increase of sympathetic-nerve activity resulting in surges in blood pressure.<sup>42</sup> Some other studies have also demonstrated that increased sympathetic activity due to short sleep durations may be associated with hypertension.<sup>34 43 44</sup> An increased, 24-hour, haemodynamic load due to a prolonged exposure to short sleep durations may lead to structural adaptation such as arterial or left ventricular hypertrophy remodelling, which gradually leads to the functioning of the entire cardiovascular system under high-pressure balance.<sup>45</sup> One recent study found that sleep loss might affect blood pressure reactions to stress, contributing to an increased risk of some CVD.<sup>46</sup> In addition, disrupted circadian rhythmicity and autonomic balance caused by short sleep durations may contribute to hypertension.

This analysis has several strengths. This study is based on data from a large representative sample of the Jilin population, and this prospective study minimised selection and recall biases. There were excellent response rates to sleep-duration questions, hypertension questions,

and measurements. Finally, a broad range of covariates were controlled in the analysis, including age, sex, education, marital status, income, occupation, BMI, drinking, smoking, salt intake and exercise. A limitation of this study lies in the properties of the cross-sectional study and the recall bias of self-reported sleep duration.

## CONCLUSION

The results of our study revealed a significant association between short sleep duration (<7 hours/day) and hypertension in the sample of young adults, indicating that short sleep duration is an important risk factor for hypertension in young adults. We suggest that younger adults in the Jilin Province should maintain a sufficient sleep duration. Furthermore, the Center for Disease Control and Prevention of the Jilin Province should pay close attention and publicise health damage caused by short sleep durations.

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