BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-023916
Article Type:	Research
Date Submitted by the Author:	02-May-2018
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Keywords:	Hypertension < CARDIOLOGY, EPIDEMIOLOGY, sleep

Relationship between sleep duration and hypertension in Northeast China: a cross-sectional study

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Keywords: sleep; hypertension; epidemiology;

Word count: 2704 words (excluding title page, references, figures and tables)

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 19407 adults aged 18-79 years were enrolled. The participants were divided into three groups (<7hours/d, 7-8 hours/d, >8hours/d) according to self-reported sleep duration. Hypertension was defined as SBP≥140mmHg or DBP≥90mmHg or use of anti-hypertensive medications. Univariate and multivariate logistic regressions were performed to determine the association between hypertension and sleep duration adjusted for socio-demographic, BMI, 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: 1.05-1.46), compared with those who slept 7-8 hours per day. There were no significant associations between sleep duration and hypertension among the total sample, the middle aged (45-59 years), or the old (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.

Article Summary

Strengths and limitations of this study

This study is based on data from a large, representative sample of the Jilin population, and this prospective study minimized the selection and recall bias.

There are excellent response rates to the sleep duration questions and hypertension questions and measurements.

A broad range of covariates are controlled for in the analysis, including age, sex, education, marital status, income, occupation, BMI, drinking, smoking, diet habit, and exercise.

The limitation of this study lies in the properties of the cross-sectional study and the recall bias of all self-reported sleep duration.

Introduction

In many countries, the diagnosis of hypertension is based on a systolic blood pressure(SBP) of at least 140 mmHg, a diastolic blood pressure(DBP) of at least 90 mmHg, or both[1 2]. In 2000, the overall prevalence of hypertension was 26.4% worldwide[3]. In 2010, hypertension was the leading single contributor to the global mortality, being responsible for more than 9 million deaths[4]. According to previous studies[5 6], hypertension was a major risk factor for cardiovascular disease, sudden cardiac death, diabetes mellitus, the metabolic syndrome, chronic kidney disease, and Alzheimer disease. Epidemiologic studies have shown that sleep duration is associated with hypertension[7 8]. Short sleep duration, usually defined as less than 7h, 6h or 5h/night[9], was associated with increased risk of prevalent hypertension[10 11]. The

relationship between self-reported sleep duration and hypertension was first reported as a U-shaped association in the sleep heart health study(SHHS)[12]. In the study, Gottlieb et al. found that sleep duration less than 7h/night or more than 8h/night was associated with an increased prevalence of hypertension. The results from the nation health and nutrition examination survey(NHNES) also demonstrated an association between sleep durations less than 5 hours per night and increased risk of hypertension in the same year[13]. However, there are conflicting results. A community-based 7-site study[14] came to the conclusion that sleep duration was unrelated to blood pressure cross-sectionally or longitudinally in the midlife women. Similarly, a study among non-insomniac elderly subjects[15] 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 Jilin province in northeast China. Moreover, the role of age and sex in the relationship between sleep duration and hypertension also was evaluated.

Methods

Study design and population

This study is embedded in the Jilin Provincial Chronic Disease Survey, a population-based cross-sectional study conducted from June 2012 to August 2012. Multistage stratified cluster sampling method was used to select a representative sample of community-dwelling residents who had lived in Jilin province within nine regions (Changchun, Jilin, Siping, Liaoyuan, Tonghua, Baishan, Songyuan, Baicheng and Yanbian) for at least six months. The detailed stratifying process was reported previously[16]. A total of 23050 individuals were recruited and 21435 of them completed the survey (response rate 84.9%). In this study, 2028 subjects were excluded from the statistical analyses due to any missing data on marital status, occupation, income, height, weight, systolic blood pressure or diastolic blood pressure, yielding a final sample size of 19407 subjects. Among the 2028 excluded subjects(1218 male, 809 female),

the mean age was 47.07 years(SD 13.40, range 18-79).

Ethical approval was obtained by the Ethics Committee of Jilin University School of Public Health. We adhered to the bioethics principles of the Declaration of Helsinki, and written informed consent was obtained from all participants.

Definition of major variables

After at least 5 minutes 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 Corporation, Kyoto, Japan) The mean of the two blood pressure measurements taken at 2-minute intervals were used in the analyses. In our study, hypertension was defined as SBP≥140 mmHg or DBP≥90 mmHg or 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(24h) during the past month?" The results were categorized into 3 groups for analysis: <7h/day, 7-8h/day, ≥8h/day, and we choose the category of 7-8h/day as the reference group according to previous studies[12].

A structured questionnaire was used to collect socio-demographic information of the participants, and the 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 labor, mental labor, unemployed, retired), family monthly income per capita (<1000, 1000-3000, >3000 RMB). The body mass index (BMI) was measured, calculated as weight (kg)/height squared (kg/m^2). All participants were categorized as underweight (BMI<18.5kg/m^2), normal weight (BMI=18.5 to 25kg/m^2), overweight (BMI=25.0 to 30.0kg/m^2) or obese (BMI>30.0kg/m^2)[17]. Other variables including smoking status(yes, no, former), drinking (yes, no), diet habit (high-salt, light, moderate), 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 accumulatively but had quitted 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. Drinker was defined as a person who consumed an average of more than one alcoholic drink per week. Based on self-report results, we divided the diet habits 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"; while those who usually exercised less than one time a week were defined as "never exercise".

Statistical analysis

Data were analysed using SPSS software (ver. 24.0; IBM Corp.: Armonk, NY, USA). χ^2 tests were used to test the association between hypertension and categorical potentially confounding variables. After preliminary univariate analyses, we used logistic regression models to examine the effect of sleep duration on the risk of hypertension. Four regression models were generated: the first model was conducted without adjustment for any covariates. Covariates in the first adjusted multivariate model (model 2) included age, gender, education, marital status, occupation, family per capita monthly income. Model 3 was adjusted for factors in model 2 plus BMI. And model 4 was adjusted further for smoking, drinking, diet habit, physical exercise. The dependent variable was the presence of hypertension. In addition, we performed subgroup analysis stratified by age and sex. A probability level of *P*–values less than 0.05 was considered as statistically significant.

Patient 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 to 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.

Results

The baseline characteristics of the study population according to sleep duration levels are presented in Table 1. Of the 19407 participants in our study (53.0% female; mean age: 47.53

years; SD: 13.13 years; range: 18 to 79 years), the median reported sleep duration of the study population was 7.00 h/d, 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, diet habits, exercise, and BMI.

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

Characteristic	Group	Sleep Duration			χ^2	*P*
		<7h/d	7-8h/d	>8h/d		
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(38.8)		
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(49.9)	75(20.8)	106(29.4)		
	Widowed	482(51.2)	202(21.4)	258(27.4)		
Occupation	Manual labor	3241(35.4)	2294(25.1)	3622(39.6)	172.040	<0.001
	Mental labor	2071(33.5)	1653(26.7)	2461(39.8)		
	Unemployed	741(41.0)	450(24.9)	618(34.2)		
	Retired	1053(46.7)	567(25.1)	636(28.2)		
Income(RMB)	<1000	3032(38.1)	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(38.2)	1573(25.9)	2174(35.8)		
Diet habit	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(24.8)	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)		
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)		

The characteristics of the study population are shown in table 2. In our study, the overall prevalence of hypertension was 32.6% (male 37.0%, female 28.6%) . Hypertension was found to be associated with sex, age, education, marital status, occupation, family monthly income per capita. Also, hypertension was associated with smoking, drinking, diet habit, exercise and BMI. The sleep duration was 7.0 (6.0, 8.0) h/d and 7.0 (6.5, 8.0) h/d for hypertensive and non-hypertensive individuals respectively. As shown in table 2, there was a significant difference between sleep duration and the prevalence of hypertension.

Table 2 Baseline Characteristics of the Participants

Characteristic	Group	Hypertension		χ^2	*P*	OR	95%CI
		No	Yes				
Numbers 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	(0.642-0.724)
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	(2.898-3.366)
	60-79	1757(46.2)	2044(53.8)			5.811	(5.327-6.338)
Education	Elementary	3509(60.6)	2280(39.4)	282.324	<0.001	1.000	-
	Junior	3779(67.5)	1821(32.5)			0.742	(0.687-0.801)
	Senior	3408(68.8)	1544(31.2)			0.697	(0.644-0.755)
	University	2391(78.0)	675(22.0)			0.434	(0.393-0.480)
Marital Status	Married	11201(66.7)	5581(33.3)	366.705	<0.001	1.000	-
	Unmarried	1157(87.5)	165(12.5)			0.286	(0.242-0.338)
	Separated/divorced	251(69.5)	110(30.5)			0.880	(0.701-1.103)
	Widowed	478(50.7)	464(49.3)			1.948	(1.708-2.222)
Occupation	Manual labor	6159(67.3)	2988(32.7)	417.761	<0.001	1.000	-
	Mental labor	4634(74.9)	1551(25.1)			0.688	(0.640-0.739)
	Unemployed	1107(61.2)	702(38.8)			1.303	(1.174-1.446)
	Retired	1187(52.6)	1069(47.4)			1.850	(1.685-2.031)
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	(0.701-0.795)
	>3000	1420(73.5)	513(26.5)			0.621	(0.556-0.694)
Smoking	Never	8293(69.9)	3579(30.1)	145.176	<0.001	1.000	-
	Yes	3930(65.8)	2040(34.2)			1.203	(1.126-1.285)
	Ever	864(55.2)	701(44.8)			1.880	(1.689-2.092)
Drinking	No	9306(69.8)	4034(30.2)	105.100	<0.001	1.000	-
	Yes	3781(62.3)	2286(37.7)			1.395	(1.309-1.487)
Diet habit	Moderate	4748(70.7)	1972(29.3)	50.369	<0.001	1.000	-
	High-salt	4784(65.2)	2548(34.8)			1.282	(1.194-1.3777)
	Light	3555(66.4)	1800(33.6)			1.219	(1.128-1.317)
Physical exercise	Never	6298(69.6)	2754(30.4)	283.246	<0.001	1.000	-
	Frequently	3430(59.1)	2370(40.9)			1.580	(1.475-1.693)
	Occasionally	3359(73.7)	1196(26.3)			0.814	(0.752-0.882)
BMI	Normal weight	6727(76.2)	2105(23.8)	1063.588	<0.001	1.000	-
	Underweight	752(88.9)	94(11.1)			0.359	(0.288-0.446)
	Overweight	4211(61.5)	2639(38.5)			2.172	(2.034-2.318)
	Obese	1397(48.5)	1482(51.5)			3.142	(2.787-3.542)
Sleep Duration	<7h/d	4480(63.0)	2626(37.0)	103.575	<0.001	1.000	-
	7-8h/d	3415(68.8)	1549(31.2)			1.292	(1.197-1.396)
	>8h/d	5192(70.8)	2145(29.2)			0.911	(0.842-0.985)

Table 3 shows the results of multiple logistic regressions performed to test the associations 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:1.20-1.40, model 1). After adjusting for socio-demographic variables (OR=1.09, 95%CI:1.00-1.18, model 2), socio-demographic variables and BMI (OR=1.09, 95%CI:1.00-1.18, model 3), the sleep duration of less than 7 hours per day continued to be associated with a higher risk of hypertension. But the observed association of sleep duration with hypertension was attenuated by socio-demographic variables and BMI. Then, after adjusting for socio-demographic variables, BMI, and lifestyle factors, the short sleep duration (less than 7 hours per day) was no longer associated with hypertension (OR=1.08, 95%CI:0.99-1.17, 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 longer sleep duration and hypertension (OR=0.99, 95%CI:0.91-1.07, model 2; OR=1.00, 95%CI:0.92-1.09, model 3; OR=1.01, 95%CI:0.92-1.10, model 4) (Figure 1).

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 an increased probability of hypertension after considering different covariates (OR=1.38, 95%CI:1.18-1.61, model 1; OR=1.35, 95%CI:1.15=1.59, model 2; OR=1.27,95%CI: 1.08-1.50, model 3; OR=1.24, 95%CI:1.05-1.46, model 4). However, all the 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 (Figure 2).

Repeating the analysis for male and female separately, we found that the unadjusted results were similar between male and female subjects. 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 per day (male: OR=1.24, 95%CI:1.12-1.39, model 1; female: OR=1.36, 95%CI=1.22-1.51, model 1). When socio-demographic variables, BMI, and lifestyle factors were included in the models, sleep duration was not associated with the risk of hypertension for both male and female subjects (Table 3).

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

Sleep Duration	Model 1	Model 2	Model 3	Model 4
Total				
<7h/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)
7-8h/day	1.00	1.00	1.00	1.00
≥8h/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)
Ages 18-44				
<7h/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)
7-8h/day	1.00	1.00	1.00	1.00
≥8h/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)
Ages 45-59				
<7h/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)
7-8h/day	1.00	1.00	1.00	1.00
≥8h/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)
Ages 60-79				
<7h/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)
7-8h/day	1.00	1.00	1.00	1.00
≥8h/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)

Male				
<7h/day	1.24(1.12-1.39)	1.08(0.97-1.21)	1.08(0.97-1.22)	1.06(0.94-1.191)
7-8h/day	1.00	1.00	1.00	1.00
≥8h/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)
Female				
<7h/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)
7-8h/day	1.00	1.00	1.00	1.00
≥8h/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, diet habit, physical exercise.

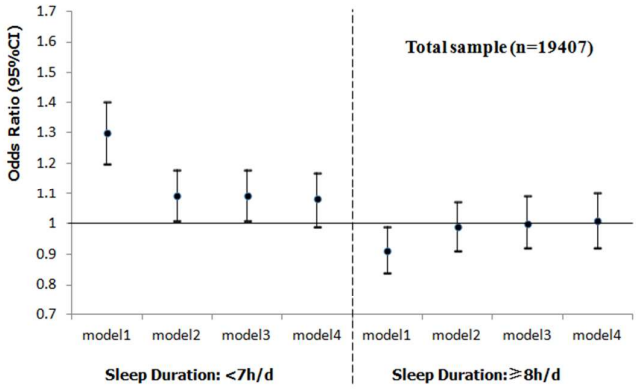

Figure 1 Odds Ratios (OR) and 95% confidence intervals (95%CI) of hypertension by sleep duration in the total population

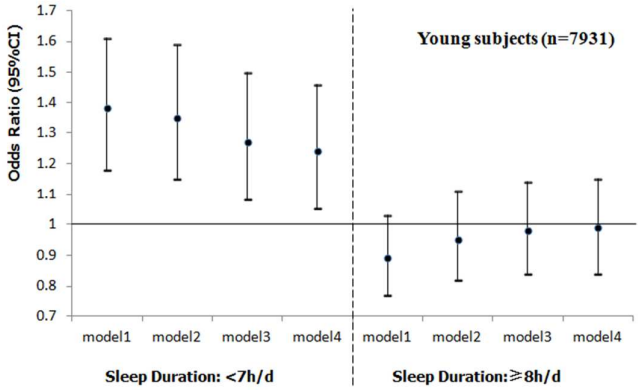

Figure 2 Odds Ratios (OR) and 95% confidence intervals (95%CI) of hypertension by sleep duration in the young subjects (aged 18-44 years)

Discussion

This present study described an analysis of the Jilin Provincial Chronic Disease Survey,

investigating the relationship between sleep duration and hypertension. In this cross-sectional study, we observed an association between short sleep duration (less than 7 hours per day) and an increased risk of hypertension in the youth (18-44 years). This association was attenuated by the inclusion in the multivariate models of socio-demographic covariates, BMI and lifestyle factors. Compared with the youth, an association between short sleep duration and hypertension was not found for the middle-aged (45-59 years), old (60-79 years) participants or the total sample. Further more, no association between sleep duration and hypertension in the male participants or the female separately was found.

There have been several studies[18-22] of the relationship between sleep duration and blood pressure. In 2006[12], Gottlieb et al found that short sleep duration (less than 7 hours per night) was associated with a higher risk of hypertension compared with a sleep duration of 7 to less than 8 hours per night in the Sleep Heart Health Study (SHHS). In the same year, Gangwisch et al[13] conducted longitudinal analyses of the first National Health and Nutrition Examination Survey, and the results showed that sleep durations of less than 5 hours per night was associated increased risk of hypertension in subjects aged 32 to 59 years. In cross-sectional and prospective analyses of the Whitehall II Study[23], short duration of sleep (less than 5 hours per night) was associated with increased risk of hypertension among women, compared with the median sleep duration of 7 hours. The result of the Whitehall II Study was different from ours, which may be caused by different study population. Recent reviews[9 24 25] and meta-analyses[26 27] further clarified the association between short sleep duration and hypertension risk. Two adult meta-analyses[10 11] showed similar results indicating that short sleep duration was associated with an increased risk of hypertension (OR=1.20, 95%CI:1.09–1.32, P<0.001; OR=1.21, 95%CI:1.09–1.34, P<0.001). A meta-analysis[26] based on 17 cohort studies demonstrated that short sleep duration increased the risk of hypertension incidence (RR=1.21, 95%CI:1.05–1.40).

The biologic mechanisms underlying the association of short sleep duration and hypertension are complex and still partly unknown. Early data indicated a lower level of sympathetic-nerve activity and blood pressure during deep non-REM sleep[28]. While during

rapid-eye-movement (REM) sleep, there is an increase of sympathetic-nerve activity resulting in surges in blood pressure[28]. Increased sympathetic activities which can be caused by short sleep duration may be associated with hypertension[29-31]. Recent studies found that sleep loss may affect blood pressure reactions to stress, contributing to an increased risk for some cardiovascular diseases[32]. In addition, disrupted circadian rhythmicity and autonomic balance caused by short sleep durations may contribute to hypertension.

There are several strengths of this analysis. This study is based on data from a large, representative sample of the Jilin population, and this prospective study minimized the selection and recall bias. There are excellent response rates to the sleep duration questions and hypertension questions and measurements. Finally, a broad range of covariates are controlled for in the analysis, including age, sex, education, marital status, income, occupation, BMI, drinking, smoking, diet habit, and exercise. The limitation of this study lies in the properties of the cross-sectional study and the recall bias of all self-reported sleep duration.

Conclusion

According to the results of our study, we demonstrated a significant association between short sleep duration (less than 7 hours per day) and hypertension in the youth sample, which indicates that short duration of sleep is an important risk factor for hypertension in the youth. We suggest that the youth in Jilin Province should maintain enough sleep duration. Further more, the CDC (Center for Disease Control and Prevention) of Jilin province should pay more attention to popularize the health damage caused by short sleep duration.

Acknowledgments

The contributions of all of the participants, patient advisers and interviewers are gratefully acknowledged. This study was supported by grants from the Center for Disease Prevention and Control in Jilin Province.

Data sharing statement

The survey was implemented by School of Public Health, Jilin University and Jilin Center for

Disease Control and Prevention in Jilin Province in 2012. According to relevant regulations, the data can not be shared.

Funding

This study was supported by a competitive grant from the Scientific Research Foundation of the Health Bureau of Jilin Province, China (grant number: 2011Z116).

Author Contributions

Formal analysis, Meng Li; Investigation, Bo Li; Methodology, Bo Li; Writing – original draft, Meng Li; Writing – review & editing, Meng Li, Shoumeng Yan, Shan Jiang, Xiaoyu Ma and Tianyu Gao.

Conflicts of Interest

The authors declare no conflict of interest.

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BMJ Open

Relationship between sleep duration and hypertension in Northeast China: a cross-sectional study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-023916.R1
Article Type:	Research
Date Submitted by the Author:	31-Aug-2018
Complete List of Authors:	Li, Meng; Jilin University School of Public Health, Department of Epidemiology and Biostatistics Yan, shoumeng; Jilin University School of Public Health, Department of Epidemiology and Biostatistics Jiang, Shan; Jilin University School of Public Health, Department of Epidemiology and Biostatistics Ma, Xiaoyu; Jilin University School of Public Health, Department of Epidemiology and Biostatistics Gao, Tianyu; Jilin University School of Public Health, Department of Epidemiology and Biostatistics; Changchun Health Supervision Institute Li, Bo
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	Hypertension < CARDIOLOGY, EPIDEMIOLOGY, sleep

Relationship between sleep duration and hypertension in Northeast China: a cross-sectional study

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Keywords: sleep; hypertension; epidemiology;

Word count: 2704 words (excluding title page, references, figures and tables)

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 h/d, 7-8 h/d, >8 h/d) according to self-reported sleep duration. Hypertension was defined as systolic blood pressure (SBP) ≥140 mmHg or diastolic blood pressure (DBP) ≥90 mmHg 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 socio-demographic, BMI, 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:1.05-1.46), compared with those who slept 7-8 hours per day. There were no significant associations between sleep duration and hypertension among the total sample, 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.

Article Summary

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 the sleep duration questions and the hypertension questions and measurements.
- A broad range of covariates were controlled for in the analysis, including age, sex, education, marital status, income, occupation, BMI, 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.

Introduction

In many countries, the diagnosis of hypertension is based on a systolic blood pressure(SBP) of at least 140 mmHg, a diastolic blood pressure(DBP) of at least 90 mmHg, or both.[1 2] In 2000, the overall prevalence of hypertension was 26.4% worldwide.[3] In 2010, hypertension was the leading single contributor to global mortality, being responsible for more than 9 million deaths.[4] Data from National Health and Nutrition Examination Survey (NHANES) in 2011-2012 estimated the overall prevalence of hypertension among U.S. adults aged 18 and over was 29.1% (29.7% men and 28.5% women).[5] The latest data from the Global Burden of Disease Study in 2015 showed that high systolic blood pressure continues to be the largest contributor to global disability-adjusted life-years (DALYs), causing 211.8 million global DALYs each year.[6] According to a previous study,[7] 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.[8 9] Short sleep duration, usually defined as less than 7 h, 6 h or 5 hours per night,[10] was associated with an increased risk of prevalent hypertension.[11 12] The relationship between self-reported sleep duration and hypertension was first reported as a U-shaped association in the Sleep Heart Health Study (SHHS).[13] In the study, Gottlieb et al. found that sleep duration 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 Nation Health and Nutrition Examination Survey (NHANES) also demonstrated an association between sleep durations of less than 5 hours per night and an increased risk of hypertension in the same year.[14] However, there are conflicting results. A community-based 7-site study[15] came to the conclusion that sleep duration was unrelated to blood pressure cross-sectionally or longitudinally in midlife women. Similarly, a study among non-insomniac elderly subjects[16] 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 multistage 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 six months. The detailed stratifying process was reported previously.[17] 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, systolic blood pressure or diastolic blood pressure, yielding a final sample size of 19 407 subjects. Among the 2028 excluded subjects (1218 males, 809 females), the mean age was 47.07 years (SD 13.40, range 18-79 years).

Ethical approval was obtained by the Ethics Committee of Jilin University School of Public Health. We adhered to the bioethics principles of the Declaration of Helsinki, and written informed consent was obtained from all participants.

Definition of major variables

After at least 5 minutes 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 Corporation, Kyoto, Japan). The mean of the two blood pressure measurements taken at 2-minute intervals was used in the analyses. In our study, hypertension was defined as SBP ≥140 mmHg or DBP ≥90 mmHg 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 h) during the past month?" The results were categorized into 3 groups for analysis: <7 , 7-8, and ≥ 8 h/d, and we chose the category of 7-8 h/d as the reference group, in accordance with a previous study.[13]

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 body mass index (BMI) was measured, calculated as weight (kg)/height squared (kg/m^2). All participants were categorized as underweight (BMI<18.5 kg/m^2), normal weight (BMI=18.5 to 25 kg/m^2), overweight (BMI=25.0 to 30.0 kg/m^2) or obese (BMI>30.0 kg/m^2).[18] 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-report 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 one time a week were defined as "never exercise".

Statistical analysis

Data were analysed using SPSS software (ver. 24.0; IBM Corp.; Armonk, NY, USA). χ^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 odds-ratio (OR) and 95% confidence intervals (CI) 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 to 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.

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% female; mean age: 47.53 years; SD: 13.13 years; range: 18 to 79 years), the median reported sleep duration of the study population was 7.00 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 male, 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 1 Characteristics of the three groups stratified according to sleep duration

Characteristic	Group	Sleep Duration			χ^2	*P*
		<7 h/d	7-8 h/d	>8 h/d		
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 labor	3241(35.4)	2294(25.1)	3622(39.5)	172.040	<0.001
	Mental labor	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)		
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)		

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% male, 28.6% female). 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 a significant difference between sleep duration and the prevalence of hypertension. Hypertensive subjects were more likely to sleep for shorter durations.

Table 2 Baseline characteristics of the participants stratified by hypertension

Characteristic	Group	Hypertension		χ^2	*P*	OR	95%CI
		No	Yes				
Numbers 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	(0.642-0.724)
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	(2.898-3.366)
	60-79	1757(46.2)	2044(53.8)			5.811	(5.327-6.338)
Education	Elementary	3509(60.6)	2280(39.4)	282.324	<0.001	1.000	-
	Junior	3779(67.5)	1821(32.5)			0.742	(0.687-0.801)
	Senior	3408(68.8)	1544(31.2)			0.697	(0.644-0.755)
	University	2391(78.0)	675(22.0)			0.434	(0.393-0.480)
Marital Status	Married	11201(66.7)	5581(33.3)	366.705	<0.001	1.000	-
	Unmarried	1157(87.5)	165(12.5)			0.286	(0.242-0.338)
	Separated/divorced	251(69.5)	110(30.5)			0.880	(0.701-1.103)
	Widowed	478(50.7)	464(49.3)			1.948	(1.708-2.222)
Occupation	Manual labor	6159(67.3)	2988(32.7)	417.761	<0.001	1.000	-
	Mental labor	4634(74.9)	1551(25.1)			0.688	(0.640-0.739)
	Unemployed	1107(61.2)	702(38.8)			1.303	(1.174-1.446)
	Retired	1187(52.6)	1069(47.4)			1.850	(1.685-2.031)
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	(0.701-0.795)
	>3000	1420(73.5)	513(26.5)			0.621	(0.556-0.694)
Smoking	Never	8293(69.9)	3579(30.1)	145.176	<0.001	1.000	-
	Yes	3930(65.8)	2040(34.2)			1.203	(1.126-1.285)
	Ever	864(55.2)	701(44.8)			1.880	(1.689-2.092)
Drinking	No	9306(69.8)	4034(30.2)	105.100	<0.001	1.000	-
	Yes	3781(62.3)	2286(37.7)			1.395	(1.309-1.487)

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	(1.194-1.3777)
	Light	3555(66.4)	1800(33.6)			1.219	(1.128-1.317)
Physical exercise	Never	6298(69.6)	2754(30.4)	283.246	<0.001	1.000	-
	Frequently	3430(59.1)	2370(40.9)			1.580	(1.475-1.693)
	Occasionally	3359(73.7)	1196(26.3)			0.814	(0.752-0.882)
BMI	Normal weight	6727(76.2)	2105(23.8)	1063.588	<0.001	1.000	-
	Underweight	752(88.9)	94(11.1)			0.359	(0.288-0.446)
	Overweight	4211(61.5)	2639(38.5)			2.172	(2.034-2.318)
	Obese	1397(48.5)	1482(51.5)			3.142	(2.787-3.542)
Sleep Duration	<7 h/d	4480(63.0)	2626(37.0)	103.575	<0.001	1.000	-
	7-8 h/d	3415(68.8)	1549(31.2)			1.292	(1.197-1.396)
	>8 h/d	5192(70.8)	2145(29.2)			0.911	(0.842-0.985)

Table 3 shows the results of multiple logistic regressions performed to test the associations 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:1.20-1.40, model 1). After adjusting for socio-demographic variables (OR=1.09, 95%CI:1.00-1.18, model 2), socio-demographic variables and BMI (OR=1.09, 95%CI:1.00-1.18, 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 socio-demographic variables and BMI. Then, after adjusting for socio-demographic variables, BMI, and lifestyle factors, a short sleep duration (less than 7 hours per day) was no longer associated with hypertension (OR=1.08, 95%CI:0.99-1.17, 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:0.91-1.07, model 2; OR=1.00, 95%CI:0.92-1.09, model 3; OR=1.01, 95%CI:0.92-1.10, 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:1.18-1.61, model 1; OR=1.35, 95%CI:1.15=1.59, model 2; OR=1.27,

95%CI:1.08-1.50, model 3; OR=1.24, 95%CI:1.05-1.46, 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 males and females separately, we found that the unadjusted results were similar between male and female subjects. 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 (males: OR=1.24, 95%CI:1.12-1.39, model 1; females: OR=1.36, 95%CI=1.22-1.51, model 1). When socio-demographic 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.

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

Sleep Duration	Model 1	Model 2	Model 3	Model 4
Total				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	0.91(0.84-0.99)	0.99(0.91-1.07)	1.00(0.92-1.09)	1.01(0.92-1.10)
Ages 18-44				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	0.89(0.77-1.03)	0.95(0.82-1.11)	0.98(0.84-1.14)	0.99(0.84-1.15)
Ages 45-59				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	1.03(0.91-1.17)	1.03(0.91-1.17)	1.03(0.91-1.17)	1.03(0.91-1.17)
Ages 60-79				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	1.06(0.89-1.26)	1.07(0.89-1.27)	1.06(0.89-1.27)	1.06(0.89-1.27)
Male				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	1.00(0.90-1.12)	1.02(0.91-1.14)	1.03(0.92-1.16)	1.04(0.92-1.17)
Female				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	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.

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 (less than 7 hours per 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 socio-demographic covariates, BMI and lifestyle factors. Compared with the young adults, an association between short sleep duration and hypertension was not found for the 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[19-23] focusing on the relationship between sleep duration and blood pressure. However, this relationship is still controversial. Recent reviews[10 24 25] and meta-analyses[26 27] further clarified the association between short sleep durations and hypertension risk. Two adult meta-analyses[11 12] showed similar results, indicating that short sleep durations were associated with an increased risk of hypertension (OR=1.20, 95%CI:1.09–1.32, P<0.001; OR=1.21, 95%CI:1.09–1.34, P<0.001). A meta-analysis[26] based on 17 cohort studies demonstrated that short sleep durations increased the risk of hypertension incidence (RR=1.21, 95%CI:1.05–1.40). 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 younger than 60 years.[28] This was consistent with a Spanish study, which demonstrated that self-reported sleep duration was not associated with hypertension in older adults.[29] 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.[30] Furthermore, participants experiencing hypertension are probably less likely to survive into their later years. In cross-sectional and prospective analyses of the Whitehall II Study,[31] short duration of sleep (less than 5 hours per 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.[32] Second, the Sleep Heart Health Study indicated that male and female participants answer questions on sleepiness differently.[33] Therefore, the differential self-reporting of sleep habits of male and female participants may have an impact on these gender-specific associations.

The biological mechanisms underlying the association of short sleep duration and hypertension are complex and not fully understood. Early data indicated a lower level of sympathetic-nerve activity and blood pressure during deep non-REM sleep.[34] During rapid-eye-movement (REM) sleep, there is an increase of sympathetic-nerve activity resulting in surges in blood pressure.[34] Some other studies have also demonstrated that increased sympathetic activity due to short sleep durations may be associated with hypertension.[35-37] 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.[38] One recent study found that sleep loss might affect blood pressure reactions to stress, contributing to an increased risk for some cardiovascular diseases.[39] 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 minimized selection and recall biases. There were excellent response rates to the sleep duration questions, hypertension questions, and measurements. Finally, a broad range of covariates were controlled for 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 (less than 7 hours per 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 (CDC) of the Jilin Province should pay close attention and publicize the health damage caused by short sleep durations.

Acknowledgments

The contributions of all of the participants, patient advisers and interviewers are gratefully acknowledged. This study was supported by grants from the Center for Disease Prevention and Control in Jilin Province.

Data sharing statement

The survey was implemented by School of Public Health, Jilin University and Jilin Center for Disease Control and Prevention in Jilin Province in 2012. According to relevant regulations, the data can not be shared.

Funding

This study was supported by a competitive grant from the Scientific Research Foundation of the Health Bureau of Jilin Province, China (grant number: 2011Z116).

Author Contributions

Formal analysis, Meng Li; Investigation, Bo Li; Methodology, Bo Li; Writing – original draft, Meng Li; Writing – review & editing, Meng Li, Shoumeng Yan, Shan Jiang, Xiaoyu Ma and Tianyu Gao.

Conflicts of Interest

The authors declare no conflict of interest.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (page 1)
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found (page 2-3)
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported (page 3-4)
Objectives	3	State specific objectives, including any prespecified hypotheses (page 4)
Methods		
Study design	4	Present key elements of study design early in the paper (page 4)
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection (page 4-5)
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants (page 4)
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable (page 4-5)
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (page 4-5)
Bias	9	Describe any efforts to address potential sources of bias (page 4)
Study size	10	Explain how the study size was arrived at (page 4)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (page 6)
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (page 6)
		(*b*) Describe any methods used to examine subgroups and interactions (page 6)
		(*c*) Explain how missing data were addressed (page 6)
		(*d*) If applicable, describe analytical methods taking account of sampling strategy (page 6)
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (page 6-7)
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (page 6-7)
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15*	Report numbers of outcome events or summary measures (page 6-9)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (page 7-8)
		(*b*) Report category boundaries when continuous variables were categorized (page7-

		10)
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (page 9-10)
Discussion		
Key results	18	Summarise key results with reference to study objectives (page 10-11)
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias (page 12)
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence (page 10-12)
Generalisability	21	Discuss the generalisability (external validity) of the study results (page 10-12)
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Relationship between sleep duration and hypertension in Northeast China: a cross-sectional study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2018-023916.R2
Article Type:	Research
Date Submitted by the Author:	20-Nov-2018
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Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	Hypertension < CARDIOLOGY, EPIDEMIOLOGY, sleep

Relationship between sleep duration and hypertension in Northeast China: a cross-sectional study

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Keywords: sleep; hypertension; epidemiology;

Word count: 2704 words (excluding title page, references, figures and tables)

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 h/d, 7-8 h/d, >8 h/d) according to self-reported sleep duration. Hypertension was defined as systolic blood pressure (SBP) ≥140 mmHg or diastolic blood pressure (DBP) ≥90 mmHg 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 socio-demographic, BMI, 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:1.05-1.46), compared with those who slept 7-8 hours per day. There were no significant associations between sleep duration and hypertension among the total sample, 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.

Article Summary

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 the sleep duration questions and the hypertension questions and measurements.
- A broad range of covariates were controlled for in the analysis, including age, sex, education, marital status, income, occupation, BMI, 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.

Introduction

In many countries, the diagnosis of hypertension is based on a systolic blood pressure(SBP) of at least 140 mmHg, a diastolic blood pressure(DBP) of at least 90 mmHg, or both.[1 2] In 2000, the overall prevalence of hypertension was 26.4% worldwide.[3] In 2010, hypertension was the leading single contributor to global mortality, being responsible for more than 9 million deaths.[4] Data from National Health and Nutrition Examination Survey (NHANES) in 2011-2012 estimated the overall prevalence of hypertension among U.S. adults aged 18 and over was 29.1% (29.7% men and 28.5% women).[5] The latest data from the Global Burden of Disease Study in 2015 showed that high systolic blood pressure continues to be the largest contributor to global disability-adjusted life-years (DALYs), causing 211.8 million global DALYs each year.[6] According to a previous study,[7] 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.[8 9] Short sleep duration, usually defined as less than 7 h, 6 h or 5 hours per night,[10] was associated with an increased risk of prevalent hypertension.[11 12] The relationship between self-reported sleep duration and hypertension was first reported as a U-shaped association in the Sleep Heart Health Study (SHHS).[13] In the study, Gottlieb et al. found that sleep duration 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 Nation Health and Nutrition Examination Survey (NHANES) also demonstrated an association between sleep durations of less than 5 hours per night and an increased risk of hypertension in the same year.[14] However, there are conflicting results. A community-based 7-site study[15] came to the conclusion that sleep duration was unrelated to blood pressure cross-sectionally or longitudinally in midlife women. Similarly, a study among non-insomniac elderly subjects[16] 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 multistage 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 six months. The detailed stratifying process was reported previously.[17] 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, systolic blood pressure or diastolic blood pressure, yielding a final sample size of 19 407 subjects. Among the 2028 excluded subjects (1218 males, 809 females), the mean age was 47.07 years (SD 13.40, range 18-79 years).

Ethical approval was obtained by the Ethics Committee of Jilin University School of Public Health. We adhered to the bioethics principles of the Declaration of Helsinki, and written informed consent was obtained from all participants.

Definition of major variables

After at least 5 minutes 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 Corporation, Kyoto, Japan). The mean of the two blood pressure measurements taken at 2-minute intervals was used in the analyses. In our study, hypertension was defined as SBP ≥140 mmHg or DBP ≥90 mmHg 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 h) during the past month?" The results were categorized into 3 groups for analysis: <7 , 7-8, and ≥ 8 h/d, and we chose the category of 7-8 h/d as the reference group, in accordance with a previous study.[13]

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 body mass index (BMI) was measured, calculated as weight (kg)/height squared (kg/m^2). All participants were categorized as underweight (BMI<18.5 kg/m^2), normal weight (BMI=18.5 to 25 kg/m^2), overweight (BMI=25.0 to 30.0 kg/m^2) or obese (BMI>30.0 kg/m^2).[18] 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-report 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 one time a week were defined as "never exercise".

Statistical analysis

Data were analysed using SPSS software (ver. 24.0; IBM Corp.; Armonk, NY, USA). χ^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 odds-ratio (OR) and 95% confidence intervals (CI) 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 to 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.

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% female; mean age: 47.53 years; SD: 13.13 years; range: 18 to 79 years), the median reported sleep duration of the study population was 7.00 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 male, 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 1 Characteristics of the three groups stratified according to sleep duration

Characteristic	Group	Sleep Duration			χ^2	*P*
		<7 h/d	7-8 h/d	>8 h/d		
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 labor	3241(35.4)	2294(25.1)	3622(39.5)	172.040	<0.001
	Mental labor	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)		
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)		

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% male, 28.6% female). 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 a significant difference between sleep duration and the prevalence of hypertension. Hypertensive subjects were more likely to sleep for shorter durations.

Table 2 Baseline characteristics of the participants stratified by hypertension

Characteristic	Group	Hypertension		χ^2	*P*	OR	95%CI
		No	Yes				
Numbers 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	(0.642-0.724)
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	(2.898-3.366)
	60-79	1757(46.2)	2044(53.8)			5.811	(5.327-6.338)
Education	Elementary	3509(60.6)	2280(39.4)	282.324	<0.001	1.000	-
	Junior	3779(67.5)	1821(32.5)			0.742	(0.687-0.801)
	Senior	3408(68.8)	1544(31.2)			0.697	(0.644-0.755)
	University	2391(78.0)	675(22.0)			0.434	(0.393-0.480)
Marital Status	Married	11201(66.7)	5581(33.3)	366.705	<0.001	1.000	-
	Unmarried	1157(87.5)	165(12.5)			0.286	(0.242-0.338)
	Separated/divorced	251(69.5)	110(30.5)			0.880	(0.701-1.103)
	Widowed	478(50.7)	464(49.3)			1.948	(1.708-2.222)
Occupation	Manual labor	6159(67.3)	2988(32.7)	417.761	<0.001	1.000	-
	Mental labor	4634(74.9)	1551(25.1)			0.688	(0.640-0.739)
	Unemployed	1107(61.2)	702(38.8)			1.303	(1.174-1.446)
	Retired	1187(52.6)	1069(47.4)			1.850	(1.685-2.031)
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	(0.701-0.795)
	>3000	1420(73.5)	513(26.5)			0.621	(0.556-0.694)
Smoking	Never	8293(69.9)	3579(30.1)	145.176	<0.001	1.000	-
	Yes	3930(65.8)	2040(34.2)			1.203	(1.126-1.285)
	Ever	864(55.2)	701(44.8)			1.880	(1.689-2.092)
Drinking	No	9306(69.8)	4034(30.2)	105.100	<0.001	1.000	-
	Yes	3781(62.3)	2286(37.7)			1.395	(1.309-1.487)

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	(1.194-1.3777)
	Light	3555(66.4)	1800(33.6)			1.219	(1.128-1.317)
Physical exercise	Never	6298(69.6)	2754(30.4)	283.246	<0.001	1.000	-
	Frequently	3430(59.1)	2370(40.9)			1.580	(1.475-1.693)
	Occasionally	3359(73.7)	1196(26.3)			0.814	(0.752-0.882)
BMI	Normal weight	6727(76.2)	2105(23.8)	1063.588	<0.001	1.000	-
	Underweight	752(88.9)	94(11.1)			0.359	(0.288-0.446)
	Overweight	4211(61.5)	2639(38.5)			2.172	(2.034-2.318)
	Obese	1397(48.5)	1482(51.5)			3.142	(2.787-3.542)
Sleep Duration	<7 h/d	4480(63.0)	2626(37.0)	103.575	<0.001	1.000	-
	7-8 h/d	3415(68.8)	1549(31.2)			1.292	(1.197-1.396)
	>8 h/d	5192(70.8)	2145(29.2)			0.911	(0.842-0.985)

Table 3 shows the results of multiple logistic regressions performed to test the associations 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:1.20-1.40, model 1). After adjusting for socio-demographic variables (OR=1.09, 95%CI:1.00-1.18, model 2), socio-demographic variables and BMI (OR=1.09, 95%CI:1.00-1.18, 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 socio-demographic variables and BMI. Then, after adjusting for socio-demographic variables, BMI, and lifestyle factors, a short sleep duration (less than 7 hours per day) was no longer associated with hypertension (OR=1.08, 95%CI:0.99-1.17, 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:0.91-1.07, model 2; OR=1.00, 95%CI:0.92-1.09, model 3; OR=1.01, 95%CI:0.92-1.10, 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:1.18-1.61, model 1; OR=1.35, 95%CI:1.15=1.59, model 2; OR=1.27,

95%CI:1.08-1.50, model 3; OR=1.24, 95%CI:1.05-1.46, 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 males and females separately, we found that the unadjusted results were similar between male and female subjects. 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 (males: OR=1.24, 95%CI:1.12-1.39, model 1; females: OR=1.36, 95%CI=1.22-1.51, model 1). When socio-demographic 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.

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

Sleep Duration	Model 1	Model 2	Model 3	Model 4
Total				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	0.91(0.84-0.99)	0.99(0.91-1.07)	1.00(0.92-1.09)	1.01(0.92-1.10)
Ages 18-44				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	0.89(0.77-1.03)	0.95(0.82-1.11)	0.98(0.84-1.14)	0.99(0.84-1.15)
Ages 45-59				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	1.03(0.91-1.17)	1.03(0.91-1.17)	1.03(0.91-1.17)	1.03(0.91-1.17)
Ages 60-79				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	1.06(0.89-1.26)	1.07(0.89-1.27)	1.06(0.89-1.27)	1.06(0.89-1.27)
Male				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	1.00(0.90-1.12)	1.02(0.91-1.14)	1.03(0.92-1.16)	1.04(0.92-1.17)
Female				
<7 h/d	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 h/d	1.00	1.00	1.00	1.00
≥8 h/d	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.

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 (less than 7 hours per 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 socio-demographic covariates, BMI and lifestyle factors. Compared with the young adults, an association between short sleep duration and hypertension was not found for the 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[19-23] focusing on the relationship between sleep duration and blood pressure. However, this relationship is still controversial. Recent reviews[10 24 25] and meta-analyses[26 27] further clarified the association between short sleep durations and hypertension risk. Two adult meta-analyses[11 12] showed similar results, indicating that short sleep durations were associated with an increased risk of hypertension (OR=1.20, 95%CI:1.09–1.32, *P*<0.001; OR=1.21, 95%CI:1.09–1.34, *P*<0.001). A meta-analysis[26] based on 17 cohort studies demonstrated that short sleep durations increased the risk of hypertension incidence (RR=1.21, 95%CI:1.05–1.40). 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 younger than 60 years.[28] This was consistent with a Spanish study, which demonstrated that self-reported sleep duration was not associated with hypertension in older adults.[29] 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.[30] Furthermore, participants experiencing hypertension are probably less likely to survive into their later years. In cross-sectional and prospective analyses of the Whitehall II Study,[31] short duration of sleep (less than 5 hours per 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.[32] Second, the Sleep Heart Health Study indicated that male and female participants answer questions on sleepiness differently.[33] 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[34 35], obstructive sleep apnea[36] and other sleep quality problems[37-39] have also been shown to be to be risk factors for hypertension. Sherwood et al[40] reported that poor sleep quality was associated with non-dipping blood pressure and the potential mechanism may be heightened sympathetic activity. Thomas et al[41] proposed other potential mechanisms including activation of the hypothalamic–pituitary–adrenal (HPA) axis and the stress-diathesis model. Unfortunately, sleep quality or sleep quality 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 and hypertension are complex and not fully understood. Early data indicated a lower level of sympathetic-nerve activity and blood pressure during deep non-REM sleep.[42] During rapid-eye-movement (REM) sleep, there is an increase of sympathetic-nerve activity resulting

in surges in blood pressure.[42] Some other studies have also demonstrated that increased sympathetic activity due to short sleep durations may be associated with hypertension.[34 43 44] 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.[45] One recent study found that sleep loss might affect blood pressure reactions to stress, contributing to an increased risk for some cardiovascular diseases.[46] 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 minimized selection and recall biases. There were excellent response rates to the sleep duration questions, hypertension questions, and measurements. Finally, a broad range of covariates were controlled for 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 (less than 7 hours per 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 (CDC) of the Jilin Province should pay close attention and publicize the health damage caused by short sleep durations.

Acknowledgments

The contributions of all of the participants, patient advisers and interviewers are gratefully acknowledged. This study was supported by grants from the Center for Disease Prevention and Control in Jilin Province.

Data sharing statement

The survey was implemented by School of Public Health, Jilin University and Jilin Center for Disease Control and Prevention in Jilin Province in 2012. According to relevant regulations, the data can not be shared.

Funding

This study was supported by a competitive grant from the Scientific Research Foundation of the Health Bureau of Jilin Province, China (grant number: 2011Z116).

Author Contributions

Formal analysis, Meng Li; Investigation, Bo Li; Methodology, Bo Li; Writing – original draft, Meng Li; Writing – review & editing, Meng Li, Shoumeng Yan, Shan Jiang, Xiaoyu Ma and Tianyu Gao.

Conflicts of Interest

The authors declare no conflict of interest.

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (page 1)
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found (page 2-3)
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported (page 3-4)
Objectives	3	State specific objectives, including any prespecified hypotheses (page 4)
Methods		
Study design	4	Present key elements of study design early in the paper (page 4)
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection (page 4-5)
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants (page 4)
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable (page 4-5)
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group (page 4-5)
Bias	9	Describe any efforts to address potential sources of bias (page 4)
Study size	10	Explain how the study size was arrived at (page 4)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why (page 6)
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (page 6)
		(*b*) Describe any methods used to examine subgroups and interactions (page 6)
		(*c*) Explain how missing data were addressed (page 6)
		(*d*) If applicable, describe analytical methods taking account of sampling strategy (page 6)
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (page 6-7)
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (page 6-7)
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15*	Report numbers of outcome events or summary measures (page 6-9)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (page 7-8)
		(*b*) Report category boundaries when continuous variables were categorized (page7-

		10)
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses (page 9-10)
Discussion		
Key results	18	Summarise key results with reference to study objectives (page 10-11)
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias (page 12)
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence (page 10-12)
Generalisability	21	Discuss the generalisability (external validity) of the study results (page 10-12)
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.