Sleep Breath (2016) 20:1355–1362
DOI 10.1007/s11325-016-1392-2

EPIDEMIOLOGY • ORIGINAL ARTICLE

Short sleep duration is associated with increased risk of pre-hypertension and hypertension in Chinese early middle-aged females

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Received: 3 March 2016 / Revised: 5 July 2016 / Accepted: 25 July 2016 / Published online: 4 August 2016

Abstract

Purpose The aim of this study is to investigate the relationship between sleep duration and hypertension in a middle-aged Chinese population.

Methods Cross-sectional data of 20,505 individuals aged 35–64 years from Taizhou longitudinal study was used. Logistic regression models were used to calculate odds ratios (ORs) for the risk of pre-hypertension and hypertension in association with sleep duration.

Results Short sleep duration was associated with high systolic and diastolic blood pressure in comparison with sleep duration of 7–8 h in females. Short sleep duration was also associated with an increased risk of hypertension in females. Age-stratified analysis showed that as compared with sleep duration of 7–8 h, sleep duration <6 h increased risk of hypertension after controlling for multiple covariates with an OR of 1.766 (1.024–2.775) in early middle-aged females of 35–44 years. More importantly, sleeping less than 6 h is associated with increased risk of pre-hypertension in females of this age category, after controlling for multiple covariates with an OR of 1.769 (1.058–2.958).

Conclusions Sleeping less than 6 h a day is associated with increased risk of pre-hypertension and hypertension in Chinese early middle-aged females. The high-risk populations require sufficient sleep, which could probably prevent the increased risk of pre-hypertension as well as hypertension.

Keywords Sleep duration · Pre-hypertension · Hypertension · Middle-aged population · Female

Introduction

Hypertension is a clinical symptom increasing the risk for cardiovascular events, renal disease, and other adverse outcomes [1, 2]. Current mechanisms of hypertension include over activity of sympathetic nervous system, renal water sodium retention, over activity of renin–angiotensin–aldosterone system, and abnormal cell membrane ion transport. Proposed risk factors of hypertension include gender, age, salt intake, obesity, and mental health, and new risk factors are being discovered continuously [3, 4].

During the past decade, abnormal sleep duration as a risk factor of hypertension has been studied. Short sleep duration, even long sleep duration, was found to be associated with the prevalence of hypertension, mainly in middle-aged

Xun-ming Sun and Shun Yao contributed equally to this work

All authors have read and approved the manuscript submitted. No part of the submitted work has been published or is under consideration for publication elsewhere, in whole or in part, in any language.

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populations [5–9]. Gender-specific association was also frequently observed [5, 10–12]. However, existing studies were mainly conducted in western populations. As Europe–Asia culture differences play important role in sleep habit, hence, the relationship between sleep duration and hypertension might be differential [13]. Studies conducted in populations outside western population ought to be assessed before the conclusion can be generalized. To our knowledge, no large population-based study on this issue has been reported in Chinese people. More importantly, we only have very limited knowledge on the association between sleep duration and pre-hypertension, which is a very important phase of abnormal blood pressure. Using data from a large population-based cohort, Taizhou longitudinal study, we explored the association between sleep duration and risk of hypertension in middle-aged Chinese. Since gender difference on sleep duration and hypertension has been reported in the literature [5, 11], we presented data stratified by gender.

Methods

Study participants

About five million residents live in Taizhou city, Jiangsu province, which is located in the east of China. According to the official statistics of the Taizhou government, the ratio of urban and rural dwellers in Taizhou is 6:4[14]. Initiated on July 2007, the Taizhou longitudinal study (TZL) is an ongoing open-ended prospective study to explore the risk factors of common non-communicable diseases in Taizhou, China. The study design and characteristics of the study have been described previously [15]. Briefly, phase III of TZL was conducted from 2011 to 2013 and a total of 23,384 Chinese Han participants were recruited from the general population using a multistage random cluster sampling method with a response rate of 65.1 %. After ruling out those who lacked of information about sleep habits, blood pressure, and covariates, 20,505 subjects were included in this study. The percentages of illiteracy/primary school and junior middle school for female in this study are 50.8 and 37.3 %, respectively, which is 26.0 and 48.5 % for male, respectively (Table 1). Approximately 76.3 % of the males and 44.0 % of the females worked in industry.

Information on demographic and socioeconomic characteristics, life-style factors, occupational exposure, personal disease history, and anthropometric measurements was collected using a structured questionnaire. Blood samples were drawn into EDTA vacutainer tubes and kept in a portable Styrofoam box with ice packs (0–4 °C) and were processed within 6 h. Immediately after processing, the samples were stored at −80 °C freezers. Written informed consents were obtained from all participants prior to participation, and the Human Ethics Committee of School of Life Science of Fudan University approved the study.

Assessment of hypertension

Blood pressure was measured by well-trained investigators using automatic blood pressure meter. Normal blood pressure: systolic blood pressure <130 mmHg and diastolic blood pressure <85 mmHg and currently not having antihypertensive treatment. Hypertension: systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg or currently having antihypertensive treatment. Pre-hypertension: Other subjects with blood pressure between 130/85 and 140/90 mmHg [16].

Assessment of sleep duration

Sleep duration was obtained with an open-ended question in the baseline questionnaire "How many hours do you sleep in a day?", and the answers were categorized into five groups, "less than 6 hours," "6 to 6.9 hours," "7 to 7.9 hours" (reference sleep duration), "8 to 8.9 hours," and "more than 9 hours" per day. Insomnia was also measured. Participants who answered "yes" to at least one of the three questions (cannot sleep within 30 min on bed, wake early in the morning, need drug help to sleep) was classified as "insomnia."

Covariates

Covariates included information obtained by questionnaires, anthropometric measurements, and blood sample collection. Smoking was defined by "at least one cigarette every day to three days during past six months," and answers were divided into three categories as "current (having during last 6 months or more)," "quitted over a year," and "never." Alcohol intake was assessed based on the responses to the following question: "Did you have the habit of drinking alcohol (at least once in a week during the past six months)," and answers were defined by "current (having in last 6 months or more)," "quitted over a year," and "never." Answers to "marriage status" was divided into "married," "never married," and "divorced or widowhood." Educational level was divided

Table 1 Basic information in males and females

	Sleep duration group	Total	<6 h	6–7 h	7–8 h	8–9 h	≥9 h	*p* value
Males	Population	7857	464	1246	1908	2636	1603	
	Age, years, $(\bar{x} \pm S)$	51.8 ± 8.2	53.6 ± 7.7	52.4 ± 7.9	51.4 ± 8.1	51.4 ± 8.4	51.9 ± 8.3	<0.001
	Marriage, *n* (%)							0.001
	Divorced/widowhood	196 (2.5)	19 (4.1)	34 (2.7)	48 (2.5)	64 (2.4)	31 (1.9)	
	Not married	138 (1.8)	17 (3.7)	15 (1.2)	24 (1.3)	45 (1.7)	37 (2.3)	
	Currently married	7523 (95.7)	428 (92.2)	1197 (96.0)	1836 (96.2)	2527 (95.9)	1535 (95.8)	
	Education, *n* (%)							<0.001
	Junior college or above	473 (6.0)	16 (3.4)	77 (6.2)	160 (8.4)	171 (6.5)	49 (3.1)	
	Senior middle school	1532 (19.5)	84 (18.1)	249 (20.0)	411 (21.5)	498 (18.9)	290 (18.1)	
	Junior middle school	3807 (48.5)	208 (44.8)	600 (48.2)	910 (47.7)	1306 (49.5)	783 (48.8)	
	Primary school or illiteracy	2045 (26.0)	156 (33.6)	220 (17.7)	327 (17.1)	661 (25.1)	481 (30.0)	
	Smoking, *n* (%)							0.910
	Always	4921 (62.7)	280 (60.5)	787 (63.2)	1208 (63.3)	1644 (62.4)	1002 (62.5)	
	Quitted over a year	763 (9.7)	51 (11.0)	123 (9.9)	179 (9.4)	246 (9.3)	164 (10.2)	
	Never	2170 (27.6)	132 (28.5)	336 (27.0)	520 (27.3)	745 (28.3)	437 (27.3)	
	Alcohol intake, *n* (%)							0.008
	Always	3814 (48.6)	234 (50.6)	627 (50.3)	940 (49.3)	1222 (46.4)	791 (49.3)	
	Quit	398 (5.1)	33 (7.1)	50 (4.0)	81 (4.2)	140 (5.3)	94 (5.9)	
	Never	3642 (46.4)	195 (42.2)	569 (45.7)	887 (46.5)	1273 (48.3)	718 (44.8)	
	BMI, kg/m^2, $(\bar{x} \pm S)$	24.7 ± 3.1	24.1 ± 3.2	24.6 ± 3.2	24.8 ± 3	24.7 ± 3.2	24.6 ± 3.2	0.001
	SBP, mmHg, $(\bar{x} \pm S)$	139.1 ± 19.1	137.4 ± 18.2	138.9 ± 19.6	139.5 ± 18.8	139.0 ± 18.7	139.5 ± 19.9	0.278
	DBP, mmHg, $(\bar{x} \pm \mathrm{S})$	84.2 ± 12.4	83.1 ± 11.9	84.1 ± 12.7	84.1 ± 12.2	84.4 ± 12.1	84.6 ± 13.2	0.269
	Hypertension, *n* (%)	4123 (52.5)	237 (51.1)	651 (52.1)	1002 (52.5)	1370 (52)	863 (53.8)	0.764
	Fasting glucose, mmol/L,$(\bar{x} \pm S)$	5.4 ± 1.8	5.3 ± 1.4	5.5 ± 1.7	5.4 ± 1.6	5.5 ± 2.0	5.4 ± 1.7	0.264
	WC	85.1 ± 9.1	83.7 ± 9.7	84.8 ± 9.4	85.4 ± 8.8	85.3 ± 8.9	85.0 ± 9.3	0.004
	Diabetes	585 (7.4)	32 (6.9)	95 (7.6)	151 (7.9)	234 (8.9)	148 (9.2)	0.273
	Metabolic syndrome	2134 (27.8)	90 (20)	335 (27.7)	532 (28.6)	714 (27.6)	463 (29.5)	0.003
Females								
	Population	12648	1006	1955	3119	4133	2435	
	Age, years, $(\bar{x} \pm S)$	50.8 ± 8	53.5 ± 7.3	51.7 ± 7.6	50.4 ± 7.9	50.0 ± 8.0	51.0 ± 8.2	<0.001
	Marriage, *n* (%)							<0.001
	Divorced/widowhood	805 (6.4)	101 (10)	150 (7.7)	184 (5.9)	222 (5.4)	148 (6.1)	
	Not married	4 (0.0)	1 (0.1)	1 (0.1)	0 (0.0)	1 (0.0)	1 (0.0)	
	Currently married	11,839 (93.6)	904 (89.9)	1804 (92.3)	2935 (94.1)	3910 (94.6)	2286 (93.9)	
	Education, *n* (%)							<0.001
	Junior college or above	289 (2.3)	15 (1.5)	41 (2.1)	107 (3.4)	91 (2.2)	35 (1.4)	
	Senior middle school	1214 (9.6)	87 (8.6)	197 (10.1)	355 (11.4)	426 (10.3)	149 (6.1)	
	Junior middle school	4722 (37.3)	278 (27.6)	770 (39.4)	1232 (39.5)	1620 (39.2)	822 (33.8)	
	Primary school or illiteracy	6423 (50.8)	626 (62.2)	947 (48.4)	1425 (45.7)	1996 (48.3)	1429 (58.7)	
	Smoking, *n* (%)							0.002
	Always	95 (0.8)	15 (1.5)	27 (1.4)	19 (0.6)	21 (0.5)	13 (0.5)	
	Quitted over a year	15 (0.1)	2 (0.2)	2 (0.1)	3 (0.1)	5 (0.1)	3 (0.1)	
	Never	12,536 (99.1)	987 (98.3)	1926 (98.5)	3097 (99.3)	4107 (99.4)	2419 (99.3)	
	Alcohol intake, *n* (%)							0.001
	Always	367 (2.9)	38 (3.8)	50 (2.6)	85 (2.7)	118 (2.9)	76 (3.1)	
	Quit	66 (0.5)	14 (1.4)	10 (0.5)	10 (0.3)	15 (0.4)	17 (0.7)	
	Never	12,211 (96.6)	952 (94.8)	1895 (96.9)	3023 (97)	3999 (96.8)	2342 (96.2)	
	BMI, kg/m^2, $(\bar{x} \pm S)$	24.5 ± 3.2	24.3 ± 3.2	24.4 ± 3.2	24.5 ± 3.2	24.6 ± 3.2	24.7 ± 3.2	<0.001
	SBP, mmHg, $(\bar{x} \pm S)$	135.3 ± 20.3	137.4 ± 19.5	135.9 ± 20.1	134.4 ± 20.3	134.7 ± 20	136.0 ± 21.1	<0.001
	DBP, mmHg, $(\bar{x} \pm S)$	80.0 ± 12.0	80.9 ± 11.6	80.1 ± 11.8	79.5 ± 12.1	79.8 ± 11.9	80.4 ± 12.3	0.005
	Hypertension, *n* (%)	5449 (43.1)	467 (46.4)	878 (44.9)	1297 (41.6)	1733 (41.9)	1074 (44.1)	0.01
	Fasting glucose, mmol/L, $(\bar{x} \pm S)$	5.3 ± 1.5	5.4 ± 1.5	5.3 ± 1.4	5.3 ± 1.2	5.3 ± 1.6	5.4 ± 1.9	0.002
	WC	80.6 ± 8.7	80.5 ± 8.7	80.2 ± 8.7	80.1 ± 8.7	80.7 ± 8.6	81.5 ± 8.8	<0.001
	Diabetes	707 (5.6)	86 (8.5)	121 (6.2)	183 (5.9)	265 (6.4)	175 (7.2)	0.026
	Metabolic syndrome	4063 (33.1)	325 (33.2)	630 (33.3)	968 (32.1)	1330 (33.1)	810 (34.0)	0.671
	Postmenopausal, *n* (%)	6743 (53.3)	688 (68.6)	1136 (58.1)	1576 (50.5)	2034 (49.2)	1309 (53.8)	<0.001

into primary school or less, junior high school, senior high school, and college or above. To compute body mass index (BMI; kg/m^2), we used heights and weights measured from physical examination. Glucose level was assessed using blood sample collected after overnight fasting of study subjects.

Statistical analyses

Continuous variables are presented as means ± SD. Categorical variables are presented as numbers and proportions. Differences in basic information among different sleep hours were compared using independent samples *t* test, non-parametric test, or chi-square test, as appropriate. Logistic regression models were used to calculate unadjusted and adjusted odds ratios (ORs) and 95 % confidence intervals (CIs) for the risk of hypertension and pre-hypertension associated with shorter or longer duration of sleep relative to a reference sleep category. The reference category has been "Normal Blood Pressure" group all through the analysis. All analyses were performed using SPSS 18.0 in this study.

Results

We found that for females, average systolic blood pressure of those sleeping less than 6 h a day (137.4 ± 19.5 mmHg), 6–7 h a day (135.9 ± 20.1 mmHg) and 9 h above (136 ± 21.1 mmHg) was significantly higher than those of the reference category (sleeping 7–8 h a day) (134.4 ± 20.3 mmHg, p value of <0.001, 0.013, and 0.003, respectively). Average diastolic blood pressure among those sleeping less than 6 h a day (80.9 ± 11.6 mmHg) and 9 h above (80.4 ± 12.3 mmHg) was also significantly higher than the reference group (79.5 ± 12.1 mmHg, p value of 0.001 and 0.005). In comparison with the reference category (41.6%), women sleeping <6 h (46.4%), 6–7 hours (44.9%) and >9 h (44.1%) were significantly more likely to develop hypertension (p value of 0.007, 0.032, and 0.011). Additionally for females, marriage status, education level, smoking and drinking condition, BMI, fasting glucose, and menopause status were all significantly different among five sleep duration categories ($p < 0.01$). Details are shown in Table 1.

With reference group as "Normal Blood Pressure" category, short sleep duration was associated with an increased risk of hypertension for females. ORs (95 % CIs) of hypertension for sleeping 6–7 h, sleeping less than 6 h, and sleeping more than 9 h were 1.169(1.034–1.322), 1.307(1.118–1.528), and 1.139(1.015–1.279), respectively, using sleeping 7–8 h as reference category. However, the associations diminished as soon as age was adjusted, suggesting age acted as a confounder to the association (Table 2). After additionally stratifying by age groups, we found that in females between 35 and 44 years old, sleeping less than 6 h increased the risk of pre-hypertension (OR 1.769, 1.058–2.958) as well as hypertension (OR 1.766, 1.024–2.775) after full adjustment (model 3). Detailed results are presented in Table 3 and Fig. 1. The results were similar in females after removing those who reported insomnia (data not shown). Nevertheless, the aforementioned association was not observed in male group (Table 4).

Discussion

Based on a large sample-sized community association study, we discovered that sleeping less than 6 h a day is associated with increased risk of pre-hypertension, in addition to hypertension during early stage of middle-aged

Table 2 Odds ratios and 95% confidence intervals for hypertension associated with sleep duration, in males and females respectively

	<6 h	6–7 h	7–8 h	8–9 h	≥9 h
Males					
Model 1	0.953 (0.754–1.205)	0.939 (0.797–1.106)	1	0.963 (0.840–1.103)	0.986 (0.847–1.149)
Model 2	0.848 (0.668–1.077)	0.896 (0.759–1.059)	1	0.961 (0.837–1.104)	0.966 (0.827–1.128)
Model 3	0.825 (0.647–1.053)	0.895 (0.755–1.060)	1	0.970 (0.842–1.117)	0.948 (0.809–1.111)
Model 4	0.954 (0.733–1.241)	0.914 (0.762–1.097)	1	0.969 (0.833–1.127)	0.997 (0.840–1.182)
Females					
Model 1	1.307 (1.118–1.528)	1.169 (1.034–1.322)	1	1.034 (0.935–1.144)	1.139 (1.015–1.279)
Model 2	0.959 (0.811–1.133)	1.041 (0.913–1.188)	1	1.073 (0.962–1.196)	1.089 (0.962–1.233)
Model 3	0.934 (0.789–1.105)	1.031 (0.903–1.176)	1	1.053 (0.944–1.174)	1.035 (0.913–1.173)
Model 4	0.999 (0.836–1.193)	1.068 (0.928–1.230)	1	1.046(0.931-1.175)	0.986 (0.863–1.127)

Model 1: not adjusted

Model 2: adjusted for age

Model 3: additionally adjusted for marriage, education, smoking and alcohol intake, menopause status (only for women)

Model 4: additionally adjusted for BMI and fasting blood glucose

Table 3 Odds ratios and 95 % confidence intervals for hypertension and pre-hypertension associated with sleep duration in females, stratified by age

		<6 h	6–7 h	7–8 h	8–9 h	≥9 h
Hypertension	35–44	*N* = 43	*N* = 88	*N* = 162	*N* = 251	*N* = 134
	Model 1	2.091 (1.382–3.164)	1.213 (0.901–1.634)	1	1.151 (0.919–1.441)	1.170 (0.901–1.520)
	Model 2	1.835 (1.198–2.811)	1.163 (0.857–1.579)	1	1.120 (0.891–1.407)	1.057 (0.810–1.379)
	Model 3	1.766 (1.024–2.775)	1.139 (0.825–1.573)	1	1.083 (0.851–1.379)	0.994 (0.749–1.319)
	45–54	*N* = 136	*N* = 338	*N* = 498	*N* = 632	*N* = 353
	Model 1	0.921 (0.705–1.203)	1.082 (0.886–1.323)	1	0.984 (0.831–1.164)	0.996 (0.819–1.211)
	Model 2	0.886 (0.676–1.161)	1.058 (0.864–1.295)	1	0.963 (0.813–1.141)	0.962 (0.789–1.173)
	Model 3	0.981 (0.737–1.306)	1.124 (0.906–1.395)	1	0.969 (0.809–1.160)	0.905 (0.733–1.116)
	55–64	*N* = 288	*N* = 452	*N* = 637	*N* = 850	*N* = 587
	Model 1	0.850 (0.671–1.078)	0.935 (0.757–1.154)	1	1.124 (0.934–1.352)	1.168 (0.952–1.432)
	Model 2	0.807 (0.635–1.026)	0.928 (0.751–1.148)	1	1.108 (0.920–1.334)	1.101 (0.896–1.353)
	Model 3	0.869 (0.672–1.124)	0.968 (0.772–1.213)	1	1.092 (0.896–1.332)	1.060 (0.850–1.321)
Pre-hypertension	35–44	*N* = 25	*N* = 52	*N* = 105	*N* = 169	*N* = 82
	Model 1	1.876 (1.139–3.089)	1.106 (0.769–1.590)	1	1.195 (0.916–1.560)	1.105 (0.806–1.515)
	Model 2	1.785 (1.078–2.957)	1.106 (0.766–1.596)	1	1.177 (0.900–1.539)	1.036 (0.754–1.424)
	Model 3	1.769 (1.058–2.958)	1.099 (0.757–1.597)	1	1.139 (0.867–1.496)	0.999 (0.723–1.381)
	45–54	*N* = 53	*N* = 110	*N* = 189	*N* = 254	*N* = 149
	Model 1	0.945 (0.661–1.353)	0.928 (0.704–1.223)	1	1.042 (0.833–1.302)	1.107 (0.857–1.431)
	Model 2	0.916 (0.637–1.317)	0.926 (0.701–1.223)	1	1.016 (0.811–1.274)	1.072 (0.827–1.388)
	Model 3	0.963 (0.668–1.389)	0.951 (0.718–1.261)	1	0.998 (0.794–1.255)	1.015 (0.781–1.321)
	55–64	*N* = 88	*N* = 131	*N* = 174	*N* = 228	*N* = 146
	Model 1	0.951 (0.690–1.310)	0.992 (0.746–1.319)	1	1.104 (0.859–1.417)	1.063 (0.805–1.404)
	Model 2	0.900 (0.651–1.245)	0.993 (0.745–1.324)	1	1.085 (0.843–1.396)	1.005 (0.758–1.331)
	Model 3	0.970 (0.698–1.349)	1.998 (0.744–1.337)	1	1.075 (0.832–1.389)	0.992 (0.744–1.321)

Model 1: not adjusted

Model 2: adjusted for marriage, education, smoking, alcohol intake, menopause status

Model 3: additionally adjusted for BMI and fasting blood glucose

females. We propose that among early middle-aged females in China, insufficient sleep of less than 6 h a day may reflect higher risk of pre-hypertension and hypertension.

This study highlighted the association between short sleep duration and pre-hypertension and considered the community population as three groups, normal BP, pre-hypertension, and hypertension, which is more specific and delicate. Pre-hypertension predisposes to hypertension and other adverse health issues at an early phase and is regarded as a reversible stage of abnormal blood pressure with great significance for prevention [17]. Our study identified short sleep as a risk factor of pre-hypertension, suggesting sleep intervention as potential preventive method for early middle-aged women. The result is in accordance with Renata Kuciene's discovery that sleep duration is associated with pre-hypertension as well as hypertension among adolescents [18].

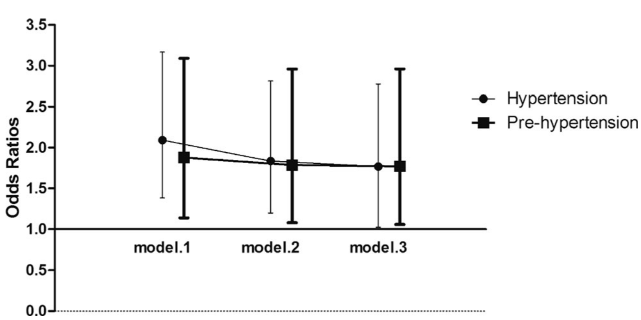

Fig. 1 ORs of hypertension and pre-hypertension for females sleeping <6 h using 7–8 h as reference

Moreover, according to previous studies, the association of sleep duration with hypertension was also observed, mainly in middle-aged populations instead of elders [5, 6, 9, 19]. In a meta-analysis with 225858 participants, Guo et al. found that short sleep duration was associated with higher risk of hypertension [20]. In another review study, James E. Gangwisch [21] discovered that in both cross-sectional and longitudinal studies, short sleep duration tend to be associated with higher risk of hypertension, especially in middle-aged adults and in female [21]. For older populations, using data from Rotterdam study, Julia F. van den Berg et al. did not find any association between short sleep duration and hypertension in elders [7]. Another study also did not find an association of short sleep duration with hypertension in Spanish elders [8]. Coincided with previous studies, we observed association of short sleep duration with hypertension in a middle-aged Chinese population rather than elders. This is also in line with another study which found that short sleep duration increases the risk of hypertension in middle-aged twin subjects [22].

The mechanisms of the association between sleep duration and hypertension remains uncertain. Several hypotheses were proposed. First, it might be due to disturbance of normal blood pressure alteration cycle decided by human bio-clock. The blood pressure descending phase during sleep might be reduced because of less sleep [23]. Second, short sleep duration may gradually alter living habit, so that people might have less interest and will power to keep on certain diet or physical practice protective for normal blood pressure [24]. Third, reduced sleep duration might boost catecholamine secretion and increase blood pressure [25]. Moreover, short sleep duration might reduce melatonin and hence elevate blood pressure [26]. In addition, it may also partially because of the difference in lifestyles between those employed middle-aged individuals and retired elders [7, 10].

Gender-specific association between short sleep duration and hypertension has been frequently reported in different populations. For example, in the NHIS cohort study, short sleep (<6 h) was associated with hypertension in women aged 65 years or above [5]. As for the Western New York study, sleeping less was associated with hypertension only in pre-menopause women [12]. In this study, we only observed the association of short sleep duration with hypertension in early middle-aged females aged 35–44 years. To note, insomnia sufferers usually under-report sleep duration, nevertheless, we still found association between short sleep (<6 h) and pre-hypertension, hypertension among non-insomnia early middle-aged women.

The mechanism of gender-specific relation between sleep duration and hypertension is largely unknown. It is certain that the physiological status, hormone secretion, metabolic status, psychological condition, and stress condition are all different between males and females [27]. First, premenopausal women require more sleep to keep metabolism and hormone secretion at higher level, and sleep deprivation is more likely to lead to high blood pressure for them [27]. Second, women tend to present mental disorders such as depression, stress, and mood fluctuation which are very likely to affect sleep, making them frailer to hypertension when they do not sleep well [28, 29]. With the rapid economic growth in China during the past few decades, the early middle-aged females are undertaking both occupational and domestic stress, which is much heavier than that of women in western countries [30]. Take our study as example, approximately 44.0 % of the females aged 64 years worked in the industry. However, when stratified by age strata, 69 % of women aged 35–44 worked in the industry. Further studies need to measure the occupational and domestic stress the early middle-aged females confronted to account for its effects on hypertension.

Limitation

First, this is a cross-sectional analysis which made it impossible to explore causal relationship between sleep duration and hypertension. Second, sleep duration was measured roughly on the scale of 24 h instead of night sleep and daytime sleep separately. Third, blood pressure has been measured almost at the same time of different days including all four seasons, bringing in bias by natural BP fluctuations, though inevitable for most large sample community study. However, there are also a few strengths of this study, such as the analysis on pre-hypertension, and the large sample size of the study with relative narrow range of age, which allowed us to conduct analysis stratified by age and sex while adjusting for important covariates to explore important issues in depth.

Conclusion

In summary, we found that sleeping less than 6 h a day is associated with pre-hypertension as well as hypertension among Chinese early middle-aged females. Chinese females aged between 35–44 years old are probably the high-risk group that requires at least 6 h of sleep to prevent the occurrence of hypertension and hypertension.

Acknowledgments This work was supported by the grants from the International cooperation project of Ministry of Science and Technology (2014DFA32830), the National Basic Research Program (2012CB944600), the National Natural Science Foundation (31171216), and the National Science & Technology Support Program (2011BAI09B00).

Compliance with ethical standards

Funding The International cooperation project of Ministry of Science and Technology provided financial support in the form of (2014DFA32830) funding, the National Basic Research Program provided financial support in the form of (2012CB944600) funding, the National Natural Science Foundation provided financial support in the form of (31171216) funding, and the National Science & Technology Support Program provided financial support in the form of (2011BAI09B00) funding.

The sponsor had no role in the design or conduct of this research.

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Written informed consents were obtained from all participants prior to participation, and the Human Ethics Committee of School of Life Science of Fudan University approved the study.

Appendix

Table 4 Odds ratios and 95 % confidence intervals for hypertension and pre-hypertension associated with sleep duration in males, stratified by age

		<6 h	6–7 h	7–8 h	8–9 h	≥9 h
Hypertension	35–44	*N* = 24	*N* = 95	*N* = 182	*N* = 248	*N* = 150
	Model 1	0.730 (0.387–1.377)	0.808 (0.560–1.167)	1	1.007 (0.760–1.334)	0.925 (0.671–1.276)
	Model 2	0.739 (0.407–1.342)	0.877 (0.616–1.248)	1	0.911 (0.690–1.202)	0.904 (0.690–1.202)
	Model 3	0.795 (0.407–1.552)	0.840 (0.567–1.244)	1	0.876 (0.645–1.189)	1.032 (0.729–1.460)
	45–54	*N* = 63	*N* = 215	*N* = 329	*N* = 462	*N* = 254
	Model 1	0.722 (0.463–1.127)	0.944 (0.702–1.270)	1	1.070 (0.836–1.370)	0.952 (0.718–1.262)
	Model 2	0.726 (0.476–1.107)	0.927 (0.698–1.231)	1	1.058 (0.834–1.342)	0.920 (0.701–1.207)
	Model 3	0.825 (0.525–1.295)	0.901 (0.666–1.220)	1	1.043 (0.809–1.345)	0.908 (0.679–1.215)
	55–64	*N* = 150	*N* = 341	*N* = 491	*N* = 660	*N* = 459
	Model 1	1.102 (0.763–1.591)	0.960 (0.725–1.271)	1	0.948 (0.746–1.205)	1.080 (0.830–1.406)
	Model 2	0.936 (0.658–1.333)	0.899 (0.691–1.171)	1	0.917 (0.732–1.149)	0.997 (0.777–1.280)
	Model 3	1.122 (0.770–1.636)	0.995 (0.752–1.317)	1	0.960 (0.756–1.219)	1.065 (0.817–1.388)
Pre-hypertension	35–44	*N* = 18	*N* = 46	*N* = 107	*N* = 154	*N* = 68
	Model 1	1.072 (0.563–2.039)	0.718 (0.470–1.096)	1	1.002 (0.732–1.372)	0.739 (0.508–1.075)
	Model 2	1.084 (0.565–2.077)	0.730 (0.477–1.119)	1	1.002 (0.729–1.375)	0.726 (0.496–1.062)
	Model 3	1.117 (0.570–2.190)	0.754 (0.486–1.169)	1	1.004 (0.724–1.391)	0.772 (0.522–1.143)
	45–54	*N* = 28	*N* = 77	*N* = 124	*N* = 149	*N* = 86
	Model 1	0.881 (0.526–1.473)	0.890 (0.622–1.275)	1	0.888 (0.656–1.200)	0.840 (0.595–1.186)
	Model 2	0.824 (0.488–1.390)	0.874 (0.608–1.257)	1	0.871 (0.642–1.183)	0.835 (0.588–1.187)
	Model 3	0.856 (0.502–1.459)	0.862 (0.596–1.248)	1	0.853 (0.625–1.165)	0.835 (0.584–1.193)
	55–64	*N* = 44	*N* = 90	*N* = 123	*N* = 179	*N* = 104
	Model 1	1.103 (0.703–1.731)	0.947 (0.668–1.341)	1	0.986 (0.734–1.326)	0.904 (0.648–1.262)
	Model 2	1.161 (0.731–1.844)	0.938 (0.659–1.334)	1	1.006 (0.745–1.358)	0.942 (0.671–1.323)
	Model 3	1.371 (0.852–2.206)	1.024 (0.715–1.467)	1	1.087 (0.800–1.477)	1.007 (0.712–1.425)

Model 1: not adjusted

Model 2: adjusted for marriage, education, smoking, alcohol intake

Model 3: additionally adjusted for BMI and fasting blood glucose

Reference

1. Tozawa M, Iseki K, Iseki C, Kinjo K, Ikemiya Y, Takishita S (2003) Blood pressure predicts risk of developing end-stage renal disease in men and women. Hypertension 41(6):1341–1345. doi:10.1161/01.hyp.0000069699.92349.8c
2. Rapsomaniki E, Timmis A, George J, Pujades-Rodriguez M, Shah AD, Denaxas S, White IR, Caulfield MJ, Deanfield JE, Smeeth L, Williams B, Hingorani A, Hemingway H (2014) Blood pressure and incidence of twelve cardiovascular diseases: lifetime risks, healthy life-years lost, and age-specific associations in 125 million people. The Lancet 383(9932): 1899–1911. doi:10.1016/s0140-6736(14)60685-1
3. Kienreich K, Tomaschitz A, Verheyen N, Pieber T, Gaksch M, Grübler M, Pilz S (2013) Vitamin D and cardiovascular disease. Nutrients 5(8):3005–3021. doi:10.3390/nu5083005
4. Xi B, Zhao X, Chandak GR, Shen Y, Cheng H, Hou D, Wang X, Mi J (2013) Influence of obesity on association between genetic variants identified by genome-wide association studies and hypertension risk in Chinese children. American journal of hypertension 26(8):990–996. doi:10.1093/ajh/hpt046
5. Fang J, Wheaton AG, Keenan NL, Greenlund KJ, Perry GS, Croft JB (2012) Association of sleep duration and hypertension among US adults varies by age and sex. American journal of hypertension 25(3): 335–341. doi:10.1038/ajh.2011.201
6. Gangwisch JE, Heymsfield SB, Boden-Albala B, Buijs RM, Kreier F, Pickering TG, Rundle AG, Zammit GK, Malaspina D (2006) Short sleep duration as a risk factor for hypertension: analyses of the first National Health and Nutrition Examination Survey. Hypertension 47(5):833–839. doi:10.1161/01.HYP.0000217362.34748.e0
7. van den Berg JF, Tulen JH, Neven AK, Hofman A, Miedema HM, Witteman JC, Tiemeier H (2007) Sleep duration and hypertension are not associated in the elderly. Hypertension 50(3):585–589. doi:10.1161/HYPERTENSIONAHA.107.092585
8. Lopez-Garcia E, Faubel R, Guallar-Castillon P, Leon-MuÃ±oz L, Banegas JR, Rodriguez-Artalejo F (2009) Self-reported sleep duration and hypertension in older spanish adults. Journal of the American Geriatrics Society 57(4):663–668. doi:10.1111/j.1532-5415.2009.02177.x
9. Kim J, Jo I (2010) Age-dependent association between sleep duration and hypertension in the adult Korean population. American journal of hypertension 23(12):1286–1291. doi:10.1038/ajh.2010.166
10. Jackowska M, Steptoe A (2015) Sleep and future cardiovascular risk: prospective analysis from the English Longitudinal Study of Ageing. Sleep medicine 16(6):768–774. doi:10.1016/j.sleep.2015.02.530
11. Cappuccio FP, Stranges S, Kandala NB, Miller MA, Taggart FM, Kumari M, Ferrie JE, Shipley MJ, Brunner EJ, Marmot MG (2007) Gender-specific associations of short sleep duration with prevalent

and incident hypertension: the Whitehall II Study. Hypertension 50(4):693–700. doi:10.1161/HYPERTENSIONAHA.107.095471

12. Stranges S, Dorn JM, Cappuccio FP, Donahue RP, Rafalson LB, Hovey KM, Freudenheim JL, Kandala N-B, Miller MA, Trevisan M (2010) A population-based study of reduced sleep duration and hypertension: the strongest association may be in premenopausal women. Journal of Hypertension 28(5):896–902. doi:10.1097/HJH.0b013e328335d076
13. Stranges S, Dorn JM, Shipley MJ, Kandala NB, Trevisan M, Miller MA, Donahue RP, Hovey KM, Ferrie JE, Marmot MG, Cappuccio FP (2008) Correlates of short and long sleep duration: a cross-cultural comparison between the United Kingdom and the United States: the Whitehall II Study and the Western New York Health Study. American journal of epidemiology 168(12):1353–1364. doi:10.1093/aje/kwn337
14. http://www.taizhou.gov.cn/art/2016/4/20/art_27_576573.html
15. Wang X, Lu M, Qian J, Yang Y, Li S, Lu D, Yu S, Meng W, Ye W, Jin L (2009) Rationales, design and recruitment of the Taizhou Longitudinal Study. BMC Public Health 9(1):223. doi:10.1186/1471-2458-9-223
16. Chalmers J, Comm GS (1999) 1999 World Health Organization—International Society of Hypertension guidelines for the management of hypertension. Clinical and Experimental Hypertension 21(5-6):1009–1060
17. Tseng C-D, Yen AM-F, Chiu SY-H, Chen L-S, Chen H-H, Chang S-H (2012) A predictive model for risk of prehypertension and hypertension and expected benefit after population-based life-style modification (KCIS No. 24). American journal of hypertension 25(2):171–179
18. Kuciene R, Dulskiene V (2014) Associations of short sleep duration with prehypertension and hypertension among Lithuanian children and adolescents: a cross-sectional study. BMC Public Health 14(1):255
19. Knutson KLP, Van Cauter EP, Rathouz PJP, Yan LLP, Hulley SBMDMPH, Liu KP, Lauderdale DSP (2009) Association between sleep and blood pressure in midlife: The CARDIA Sleep Study. Archives of Internal Medicine 169(11):1055
20. Guo X, Zheng L Fau - Wang J, Wang J Fau - Zhang X, Zhang X Fau - Zhang X, Zhang X Fau - Li J, Li J Fau - Sun Y, Sun Y (2013) Epidemiological evidence for the link between sleep duration and high blood pressure: a systematic review and meta-analysis. Sleep Medicine 14(4):324–332
21. Gangwisch, JE (2014) A review of evidence for the link between sleep duration and hypertension. Am J Hypertens 27(10):1235–42
22. Wang H, Zee P, Reid K, Chervin RD, Patwari PP, Wang B, Li Z, Tang G, Liu X, Yang J, Xu X, Wang X (2011) Gender-specific association of sleep duration with blood pressure in rural Chinese adults. Sleep medicine 12(7):693–699. doi:10.1016/j.sleep.2010.12.019
23. Kario K, Schwartz JE, Pickering TG (2000) Changes of nocturnal blood pressure dipping status in hypertensives by nighttime dosing of α-Adrenergic blocker, Doxazosin: results from the HALT Study. Hypertension 35(3):787–794
24. Sleep in America Poll (2015) Adult Sleep Habits. Sleep Health 1(2):e1. doi:10.1016/j.sleh.2015.04.001
25. Lusardi P, Zoppi A, Preti P, Pesce RM, Piazza E, Fogari R (1999) Effects of insufficient sleep on blood pressure in hypertensive patients: a 24-h study. American journal of hypertension 12(1):63–68
26. Scheer FA, Van Montfrans GA, van Someren EJ, Mairuhu G, Buijs RM (2004) Daily nighttime melatonin reduces blood pressure in male patients with essential hypertension. Hypertension 43(2):192–197. doi:10.1161/01.HYP.0000113293.15186.3b
27. Antonijevic IA, Murck H, Frieboes RM, Holsboer F, Steiger A (1999) On the gender differences in sleep-endocrine regulation in young normal humans. Neuroendocrinology 70(4):280–287
28. Boyd A, Van de Velde S, Vilagut G, de Graaf R, O′Neill S, Florescu S, Alonso J, Kovess-Masfety V (2015) Gender differences in mental disorders and suicidality in Europe: Results from a large cross-sectional population-based study. Journal of Affective Disorders 173:245–254. doi:10.1016/j.jad.2014.11.002
29. de Graaf R, ten Have M, van Gool C, van Dorsselaer S (2012) Prevalence of mental disorders and trends from 1996 to 2009. Results from the Netherlands Mental Health Survey and Incidence Study-2. Soc Psychiatry Psychiatr Epidemiol 47(2):203–213. doi:10.1007/s00127-010-0334-8
30. Harrell S, Davis D, Joint Committee on Chinese Studies (1993) Chinese families in the Post-Mao Era. University of California Press, Berkeley