

BMJ Open Gender- and age-specific associations between sleep duration and prevalent hypertension in middle-aged and elderly Chinese: a cross-sectional study from CHARLS 2011–2012

Jing Guo,¹ Yue Fei,¹ Junqin Li,² Lisan Zhang,³ Qiong Luo,² Guangdi Chen¹

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¹Department of Public Health, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China

²Institute of Obstetrics and Gynecology, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China

³Department of Neurology, Sir Run Run Shaw Hospital, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China

Correspondence to
Dr Guangdi Chen;
chenguangdi@zju.edu.cn

ABSTRACT

Objectives: The impact of gender and age on the association between sleep duration and hypertension is not well known in Asians. The objective of this study was to analyse gender- and age-specific associations between sleep duration and prevalent hypertension in middle-aged and elderly Chinese.

Design: Secondary analysis of a cohort sample.

Setting: This study used data from the national baseline survey of the China Health and Retirement Longitudinal Study (CHARLS, 2011–2012), covering 150 counties/districts and 450 villages/resident committees from 28 provinces in China.

Participants: Community-based subjects were drawn from the CHARLS through multistage probability sampling. Overall, this study included 9086 eligible subjects aged 45 years or above.

Outcome measures: Self-reported sleep duration was obtained using a structured questionnaire. The mean of three measures of systolic blood pressure and diastolic blood pressure was calculated. By gender and age groups (45–60 years, middle-aged; ≥60 years, elderly), relationships between self-reported sleep duration and prevalent hypertension were examined using logistic regression models to estimate OR and 95% CIs.

Results: Compared with the reference group (≥7 and <8 hours/night), the group who had less sleep (<6 hours/night) had a higher likelihood of hypertension in the whole sample (OR 1.26, 95% CI 1.04 to 1.52). Significant ORs (95% CIs) of hypertension were 1.68 (1.17 to 2.42), 1.69 (1.11 to 2.59) and 2.21 (1.29 to 3.80) for <6, 6–7 (≥6 and <7) and 8–9 (≥8 and <9) hours/night, respectively, in middle-aged men but not women. Interestingly, a significant association was observed between long sleep duration (≥9 hours/night) and hypertension in middle-aged women (OR 1.55, 95% CI 1.02 to 2.35) but not in men.

Conclusions: Extremes of sleep duration increased the likelihood of prevalent hypertension in middle-aged Chinese depending on gender, suggesting that appropriate strategies for improvement in sleep health are required.

Strengths and limitations of this study

- This study is representative of the general population based on the latest national cohort (China Health and Retirement Longitudinal Study, CHARLS) in accordance with internationally acceptable standards.
- This is the first study to use the general population to examine associations between sleep duration and prevalent hypertension in middle-aged and elderly Chinese.
- This study was a cross-sectional analysis with missing data and declined response rate.
- This study did not explore the relationship between sleep quality and hypertension prevalence.

INTRODUCTION

Increased blood pressure (BP) is considered to be the most treatable cause of premature death regardless of socioeconomic conditions.¹ Essential hypertension, exact causes unknown, accounts for ~95% of hypertensive cases.² Hypertension is attributable to a combination and accumulation of environmental and genetic risk factors.³ A crucial public health issue, sleep duration in the general population, which is affected by modern life and is increasingly deprived,⁴ may play an important role in the increased tendency to chronic diseases, including hypertension.⁵

Growing epidemiological evidence suggests that aberrant sleep duration is related to the risk of high BP.^{5–6} On the other hand, there are some negative reports⁷ and inconsistent results.⁸ In fact, racial disparity has been observed with respect to sleep health,⁹ BP level,¹⁰ and the association between sleep duration and risk of hypertension.¹¹ Most previous studies were conducted on caucasians and African-Americans rather than Asians.^{12–13} Studies on ethnic Chinese are

relatively rare. It was recently shown that sleep status was associated with hypertension prevalence in a community population mainly of coal miners.^{14 15} Thus, a nationwide study is warranted to obtain generalised results.

Furthermore, there are few studies on the middle-aged and elderly, who may have more sleep problems than younger people. In this study, we retrieved data from a nationally representative survey, China Health and Retirement Longitudinal Study (CHARLS), and explored associations between sleep duration and prevalent hypertension in Chinese adults aged 45 years or older.

MATERIALS AND METHODS

Data source

The CHARLS is an ongoing, longitudinal, nationwide study on the Chinese population ≥ 45 years old.¹⁶ A complex sampling design is used in the CHARLS involving multistage probability sampling to take into consideration regional and socioeconomic disparities across China. We used data from the national baseline survey of CHARLS 2011–2012, covering 150 counties/districts and 450 villages/resident committees from 28 provinces.^{16 17}

A total of 17 708 individuals were successfully interviewed, and 11 847 of these received blood tests.¹⁷ For those who agreed to blood testing, we used the following exclusion criteria: age < 45 years ($n=220$); previously diagnosed with a malignant tumour ($n=117$); current use of antidepressants, tranquilisers or sleeping pills, or receiving psychiatric or psychological treatment ($n=90$); and missing or unreasonable value of demographic, anthropometric or biomarker variables used in the data analysis ($n=2334$). Finally, 9086 observations were included in our analysis.

Measurements and definitions

Self-reported sleep duration was obtained via a structured questionnaire with the question 'During the past month, how many hours of actual sleep did you get at night (average hours for one night)?'. Systolic BP (SBP) and diastolic BP (DBP) were measured three times at 45 s intervals by trained nurses using a Omron HEM-7200 monitor (Omron (Dalian) Co, Dalian, China).¹⁶ The mean of the three measures was calculated. Weight (measured using Omron HN-286 scales; Krell Precision (Yangzhou) Co, Yangzhou, China) and height (measured with a Seca213 stadiometer; Seca Trading (Hangzhou) Co, Hangzhou, China) were measured with subjects wearing light indoor clothes.¹⁶ Other demographic and behaviour-associated information was collected by face-to-face interview. Detailed interview questions can be found in the baseline questionnaire of CHARLS 2011–2012¹⁸ (see online supplementary table S1).

Blood samples were stored at -70°C at the Chinese Center for Disease Control and Prevention (CDC) and examined at the Youanmen Center Clinical Laboratory of Capital Medical University. Concentrations of glucose, high-density lipoprotein-cholesterol (HDL), low-density

lipoprotein-cholesterol (LDL) and triglycerides were determined by an enzymatic colorimetric method, and C-reactive protein (CRP) was determined by the immunoturbidimetric assay method (2011–2012 National Baseline Blood Data Users' Guide, CHARLS).

Self-reported sleep duration was divided into five groups: < 6 , $6-7$ (≥ 6 and < 7), $7-8$ (≥ 7 and < 8), $8-9$ (≥ 8 and < 9) and ≥ 9 hours/night. Hypertension was defined as an average SBP/DBP $\geq 140/90$ mm Hg, or currently taking antihypertensive medicines, or previously being diagnosed with hypertension. Body mass index (BMI) ($\text{weight (kg)}/\text{height (m)}^2$) was categorised as underweight (< 18.5), normal weight ($18.5-24$), overweight ($24-28$) or obese (≥ 28).¹⁹ Those with a blood glucose concentration of ≥ 126 mg/dL or taking antidiabetic drugs were treated as diabetic. Dyslipidaemia was defined as elevated LDL (> 130 mg/dL) or triglyceride (≥ 150 mg/dL) concentration, decreased HDL (men < 40 mg/dL; women < 50 mg/dL) concentration²⁰ or a previous diagnosis of dyslipidaemia by a physician. The cut-off point of high CRP was defined as ≥ 3 mg/dL.²⁰

Ethics

The CHARLS was approved by the ethics committee of Peking University Health Science Center. Written informed consent was obtained from each participant.

Statistical analysis

All individuals were classified according to sleep duration. Differences in continuous and categorical variables across sleep duration groups were assessed by linear regression model and χ^2 test, respectively. Three logistic regression models with different adjustments, with sleep duration of 7–8 hours/night set as the reference, were used to explore associations between sleep duration and prevalent hypertension with respect to gender and age groups. As the mean age of the subjects was about 60 years in this study, the cut-off point for age was set at 60 years, as applied in previous studies,^{21 22} which resulted in middle-aged (≥ 45 and < 60 years) and elderly (≥ 60 years) groups. The fully adjusted model included gender, age (5-years interval), smoking (never/ever/current), drinking (never/ < 1 drink per month/ ≥ 1 drink per month), medical insurance (yes/no), BMI (underweight/normal/overweight/obese), region (rural/urban), marital status (single/married or cohabiting), educational level (illiterate/primary/junior or secondary vocational school/college and higher), regular siesta (yes/no), diabetes (yes/no), dyslipidaemia (yes/no) and high CRP (yes/no). For the complex sampling, the weight of blood sample with household and individual response adjustment was used in weighted analysis.

The first sensitivity analysis was conducted on individuals who were not currently taking antihypertensive drugs, in order to assess the impact of antihypertensive treatment. The true effect size of exposure may be overestimated by OR when the events of interest are

prevalent in a cross-sectional study.²³ Therefore, the prevalence ratio (PR) was estimated by Poisson regression in the second sensitivity analysis.

RESULTS

Demographic characteristics

The weighted proportions of subjects with sleep durations of <6, 6–7, 7–8, 8–9 and ≥9 hours/night were 29.15%, 22.21%, 18.84%, 22.20% and 7.6%, respectively. Subjects with short or long sleep duration were more likely to be female, non-drinkers, single, illiterate and of normal weight. Those with extremes of sleep duration were more likely to reside in rural areas and not like

taking a nap after lunch. No significant differences were found in age, smoking habits, medical insurance, diabetes, dyslipidaemia and high CRP among the five sleep duration categories (table 1).

BP level and prevalence of hypertension

We calculated the mean SBP, DBP and prevalence of hypertension by gender or age group within each category of sleep duration (table 2). Mean DBP was significantly different across the sleep duration categories among all the subjects and those ≥45 and <60 years old ($p<0.05$). There was no statistical significance in any other subgroup analysis.

Table 1 Demographic characteristics of middle-aged and elderly Chinese by habitual sleep duration (CHARLS 2011–2012)

Characteristic	Sleep duration category (hours/night)					p Value
	<6	6–7 (≥6 and <7)	7–8 (≥7 and <8)	8–9 (≥8 and <9)	≥9	
Total	2693	1903	1762	1981	747	
Sleep duration, mean (SD)	4.05 (1.06)	6.01 (0.05)	7.01 (0.06)	8.00 (0.03)	9.61 (0.75)	<0.001
Age (years), mean (SD)	61.62 (10.02)	58.65 (9.21)	57.56 (9.11)	58.94 (9.62)	59.80 (10.95)	0.911
Gender, n (%)						
Male	1157 (43.53)	931 (48.97)	814 (49.21)	1001 (55.20)	344 (47.04)	0.001
Smoking, n (%)						
Never	1680 (62.24)	1134 (59.49)	1041 (58.36)	1156 (56.25)	466 (61.76)	0.288
Ever	782 (27.84)	590 (29.02)	568 (32.35)	643 (34.92)	215 (29.87)	
Current	231 (9.92)	179 (11.48)	153 (9.30)	182 (8.83)	66 (8.37)	
Drinking, n (%)						
Never	1879 (69.51)	1243 (64.94)	1138 (64.03)	1301 (60.19)	515 (68.20)	0.009
<1 drink/month	183 (7.38)	182 (9.06)	150 (9.72)	144 (6.74)	54 (9.46)	
≥1 drink/month	631 (23.11)	478 (26.00)	474 (26.25)	536 (33.06)	178 (22.34)	
Medical insurance, n (%)						
Yes	2523 (93.73)	1802 (93.99)	1663 (94.01)	1874 (94.24)	701 (93.55)	0.978
BMI (kg/m ²), n (%)						
Normal	1471 (53.04)	956 (49.78)	881 (48.80)	1025 (51.07)	417 (57.02)	0.002
Underweight	243 (8.68)	109 (5.22)	89 (5.31)	113 (5.62)	55 (7.56)	
Overweight	710 (27.54)	599 (34.76)	554 (31.90)	597 (31.07)	207 (27.48)	
Obese	269 (10.73)	239 (10.25)	238 (13.99)	246 (12.24)	68 (7.94)	
Region, n (%)						
Rural	1824 (60.12)	1149 (48.19)	1103 (53.62)	1266 (52.42)	538 (66.94)	<0.001
Urban	869 (39.88)	754 (51.81)	659 (46.38)	715 (47.58)	209 (33.06)	
Marital status, n (%)						
Single	438 (18.33)	182 (10.47)	160 (10.87)	189 (9.99)	120 (16.97)	<0.001
Married or cohabiting	2255 (81.67)	1721 (89.53)	1602 (89.13)	1792 (90.01)	627 (83.03)	
Education, n (%)						
Illiterate	931 (31.54)	462 (20.88)	401 (19.98)	518 (21.52)	264 (33.62)	<0.001
Primary	1164 (43.41)	749 (35.77)	711 (38.80)	831 (40.48)	319 (42.12)	
Junior/secondary vocational school	572 (23.77)	655 (39.13)	618 (38.45)	604 (36.36)	159 (22.77)	
College and higher	26 (1.28)	37 (4.22)	32 (2.77)	28 (1.63)	5 (1.49)	
Regular siesta, n (%)						
Yes	1232 (46.86)	1068 (52.99)	998 (55.62)	1137 (54.55)	419 (54.46)	0.022
Diabetes, n (%)						
Yes	413 (15.16)	286 (14.19)	280 (15.20)	295 (14.95)	116 (15.01)	0.960
Dyslipidaemia, n (%)						
Yes	1913 (72.17)	1343 (73.37)	1235 (69.81)	1385 (71.89)	516 (68.41)	0.340
High C-reactive protein, n (%)						
Yes	507 (19.54)	335 (17.78)	307 (18.71)	316 (17.37)	148 (18.92)	0.807

BMI, body mass index; CHARLS, China Health and Retirement Longitudinal Study.

Table 2 Mean SBP, mean DBP, hypertension prevalence and BP control in middle-aged and elderly Chinese by habitual sleep duration (CHARLS 2011–2012)

	Sleep duration category (hours/night)					p Value
	<6	6–7 (≥6 and <7)	7–8 (≥7 and <8)	8–9 (≥8 and <9)	≥9	
All	n=2693	n=1903	n=1762	n=1981	n=747	
SBP, mean (SD)	131.93 (22.83)	132.33 (21.37)	129.55 (20.90)	131.44 (19.86)	131.25 (23.49)	0.107*
DBP, mean (SD)	75.47 (12.39)	76.72 (12.07)	75.75 (12.12)	77.12 (11.93)	76.58 (13.19)	0.015*
Hypertension, n (%)	1194 (45.43)	795 (42.45)	659 (37.15)	811 (43.07)	326 (41.92)	0.083
Sex						
Male	n=1157	n=931	n=814	n=1001	n=344	
SBP, mean (SD)	131.43 (22.04)	132.14 (19.27)	129.67 (19.74)	132.24 (18.04)	129.31 (21.63)	0.354*
DBP, mean (SD)	75.85 (12.85)	77.00 (11.96)	76.34 (12.33)	78.32 (11.86)	76.55 (13.18)	0.068*
Hypertension, n (%)	474 (43.86)	405 (43.32)	292 (33.97)	415 (45.36)	143 (36.79)	0.102
Female	n=1536	n=972	n=921	n=980	n=403	
SBP, mean (SD)	132.31 (23.43)	132.52 (23.22)	129.43 (22.01)	130.45 (22.08)	132.98 (24.96)	0.128*
DBP, mean (SD)	75.18 (12.02)	76.44 (12.18)	75.19 (11.87)	75.63 (11.71)	76.60 (13.20)	0.072*
Hypertension, n (%)	720 (46.64)	390 (41.62)	367 (40.24)	396 (40.26)	183 (46.48)	0.167
Age						
≥45 and <60 years	n=1244	n=1073	n=1080	n=1112	n=392	
SBP, mean (SD)	126.22 (19.62)	130.59 (20.67)	126.15 (19.08)	128.02 (18.15)	125.64 (20.03)	0.073*
DBP, mean (SD)	75.74 (12.40)	78.27 (12.28)	76.32 (12.18)	78.53 (12.30)	76.63 (13.30)	0.021*
Hypertension, n (%)	418 (33.95)	373 (36.00)	322 (28.46)	365 (37.24)	135 (33.69)	0.292
≥60 years	n=1449	n=830	n=682	n=869	n=355	
SBP, mean (SD)	136.75 (24.14)	134.82 (22.15)	135.40 (22.64)	136.32 (21.30)	138.45 (25.72)	0.718*
DBP, mean (SD)	75.24 (12.38)	74.49 (11.34)	74.78 (11.93)	75.09 (10.95)	76.50 (12.93)	0.245*
Hypertension, n (%)	776 (55.06)	422 (51.66)	337 (51.98)	446 (51.32)	191 (52.48)	0.703

*p Values of the categories of sleep duration in a linear regression model adjusted for age.

BP, blood pressure; CHARLS, China Health and Retirement Longitudinal Study; DBP, diastolic blood pressure; n, number of individuals analysed; SBP, systolic blood pressure.

Associations between sleep duration and prevalent hypertension by gender or age

For all the subjects analysed, compared with the reference group of 7–8 hours/night, we found that short duration of <6 hours/night was significantly associated with an increased risk of prevalent hypertension (OR 1.26, 95% CI 1.04 to 1.52) (table 3). For men, the multivariate-adjusted ORs (95% CI) for hypertension were 1.48 (1.17 to 1.88), 1.49 (1.11 to 2.02), 1.60 (1.01 to 2.56) and 1.17 (0.84 to 1.64) for <6, 6–7, 8–9 and ≥9 hours/night, respectively. Significant relationships were observed among individuals <60 years old, and the ORs of hypertension for those reporting <6, 6–7, 8–9 and ≥9 hours/night were 1.35 (1.07 to 1.70), 1.40 (1.02 to 1.93), 1.56 (1.06 to 2.30) and 1.52 (1.08 to 2.12), respectively. However, no significant associations were shown for women. In addition, there were no significant associations among those ≥60 years.

Associations between sleep duration and prevalent hypertension by gender and age

ORs of hypertension among groups defined by gender and age are presented in table 4. Middle-aged men with sleep duration <7 hours/night (for <6 hours/night, OR 1.68 (95% CI 1.17 to 2.42); for 6–7 hours/night, OR 1.69 (95% CI 1.11 to 2.59)) or 8–9 hours/night (OR 2.21, 95% CI 1.29 to 3.80) had a greater likelihood of

hypertension. Interestingly, middle-aged women, but not men, with extremely long sleep duration (≥9 hours/night) had more likelihood of hypertension (OR 1.55, 95% CI 1.02 to 2.35) than those sleeping for 7–8 hours/night. No significant relationships existed among the elderly of both genders. To check whether menopause affects the association between sleep duration and hypertension, the women were divided into pre- and post-menopause groups; no statistically significant results were found.

Sensitivity analysis

The relationships between self-reported sleep duration and prevalent hypertension remained robust among participants not being treated with antihypertensive drugs (see online supplementary tables S2 and S3). Compared with the corresponding OR from logistic regression, the PR from Poisson regression was attenuated (see online supplementary tables S4 and S5). The significance levels for the indices of OR and PR were very similar.

DISCUSSION

Based on the data from CHARLS, the present study demonstrates that associations between short or long sleep durations and increased likelihood of hypertension

Table 3 Associations between sleep duration and risk of hypertension in middle-aged and elderly Chinese (CHARLS 2011–2012)

	Sleep duration category (hours/night)				
	<6	6–7 (≥6 and <7)	7–8 (≥7 and <8)	8–9 (≥8 and <9)	≥9
All	n=2693	n=1903	n=1762	n=1981	n=747
Model 1†	1.17 (0.99 to 1.39)	1.20 (0.96 to 1.51)	Reference	1.22 (0.92 to 1.61)	1.10 (0.89 to 1.36)
Model 2‡	1.27 (1.05 to 1.54)*	1.24 (0.99 to 1.54)	Reference	1.26 (0.93 to 1.72)	1.25 (1.00 to 1.56)
Model 3§	1.26 (1.04 to 1.52)*	1.23 (0.99 to 1.53)	Reference	1.26 (0.93 to 1.71)	1.24 (0.99 to 1.56)
Sex					
Male	n=1157	n=931	n=841	n=1001	n=344
Model 1†	1.33 (1.06 to 1.67)*	1.43 (1.06 to 1.94)*	Reference	1.53 (0.97 to 2.41)	1.04 (0.76 to 1.42)
Model 2‡	1.48 (1.17 to 1.87)*	1.52 (1.13 to 2.04)*	Reference	1.60 (1.00 to 2.58)	1.18 (0.85 to 1.64)
Model 3§	1.48 (1.17 to 1.88)*	1.49 (1.11 to 2.02)*	Reference	1.60 (1.01 to 2.56)*	1.17 (0.84 to 1.64)
Female	n=1536	n=972	n=921	n=980	n=403
Model 1†	1.03 (0.81 to 1.33)	1.02 (0.73 to 1.44)	Reference	0.96 (0.77 to 1.21)	1.15 (0.86 to 1.53)
Model 2‡	1.08 (0.81 to 1.44)	1.01 (0.73 to 1.40)	Reference	0.97 (0.77 to 1.23)	1.28 (0.94 to 1.74)
Model 3§	1.06 (0.79 to 1.40)	1.01 (0.73 to 1.38)	Reference	0.96 (0.76 to 1.22)	1.27 (0.93 to 1.73)
Age					
≥45 and <60 years	n=1244	n=1073	n=1080	n=1112	n=392
Model 1†	1.22 (0.98 to 1.52)	1.43 (1.02 to 2.00)*	Reference	1.47 (1.00 to 2.16)*	1.27 (0.94 to 1.72)
Model 2‡	1.39 (1.10 to 1.76)*	1.45 (1.05 to 2.00)*	Reference	1.58 (1.06 to 2.36)*	1.53 (1.10 to 2.13)*
Model 3§	1.35 (1.07 to 1.70)*	1.40 (1.02 to 1.93)*	Reference	1.56 (1.06 to 2.30)*	1.52 (1.08 to 2.12)*
≥60 years	n=1449	n=830	n=682	n=869	n=355
Model 1†	1.05 (0.81 to 1.38)	0.97 (0.75 to 1.24)	Reference	0.96 (0.70 to 1.31)	0.93 (0.69 to 1.25)
Model 2‡	1.12 (0.83 to 1.51)	1.03 (0.80 to 1.32)	Reference	0.96 (0.69 to 1.33)	1.01 (0.75 to 1.38)
Model 3§	1.12 (0.84 to 1.51)	1.04 (0.81 to 1.34)	Reference	0.95 (0.68 to 1.33)	1.01 (0.74 to 1.37)

Values are OR (95% CI).

†OR adjusted for age groups and gender.

‡OR adjusted for covariates in model 1 plus BMI categories, smoking, drinking habits, the highest level of education, marital status, residential region, medical insurance, regular siesta.

§OR adjusted for covariates in model 2 plus diabetes status, dyslipidaemia and high-sensitivity C-reactive protein.

* $p < 0.05$.

BMI, body mass index; CHARLS, China Health and Retirement Longitudinal Study; n, number of subjects analysed.

varied by gender and age group. We found that middle-aged men who had short (<7 hours/night) or long (8–9 hours/night) sleep durations, as well as middle-aged women with extremely long sleep time (≥9 hours/night), were more likely to be hypertensive than subjects who had 7–8 hours of sleep per night. No statistically significant associations were detected for older subjects.

A few epidemiological studies have been previously conducted at population level to test the relationship between sleep duration and hypertension; the results were inconsistent.¹² Some researchers claimed that the associations varied by age group^{21 22 24} or gender.²⁵ On considering the effect of age, we found that middle-aged, rather than elderly, Chinese with sleep durations at either end of the spectrum were more likely to be hypertensive than the reference group. Similar disparities according to age have also been found in other countries.^{7 21} Several factors may be related to the age-dependent association. First, difficulty with sleep initiation and maintenance increases with age.²⁶ Second, sleep-disordered breathing, related to sleep loss,²⁷ was found to be associated with hypertension in people <60 years old but not in older people.²⁸ Third, sleep

duration has a close relationship with all-cause mortality,^{21 29} and people with hypertension do not survive to old age.²¹ In addition, compared with young people, older people, who are often retired, might have more opportunities to compensate for sleep deprivation at night by daytime napping.²⁴ However, the associations remained insignificant when adjustment was made for habitual siesta for elders, indicating that the effect was independent of daytime sleeping habits. Another possible explanation for the disparities between the middle-aged and elderly is that functional mechanisms that induce hypertension may play a greater role in the middle aged, while structural mechanisms (eg, large-artery stiffness) may prevail in the elderly.³⁰ Whether these factors account for the confounding effects awaits further investigation.

For the gender-specific association, some previous studies found significant results for women and not for men,^{25 31} but our study shows contradictory results. To investigate the issue in depth, we further divided the CHARLS population into four groups by age and gender, and found that short or long sleep duration for middle-aged men and extremely long sleep duration for middle-aged women were positively associated with

Table 4 Associations between sleep duration and risk of hypertension in middle-aged and elderly Chinese by gender and age groups (CHARLS 2011–2012)

Subpopulation	Sleep duration category (hours/night)				
	<6	6–7 (≥6 and <7)	7–8 (≥7 and <8)	8–9 (≥8 and <9)	≥9
Male ≥45 and <60 years	n=516	n=482	n=493	n=517	n=165
Model 1†	1.42 (1.01 to 1.99)*	1.66 (1.06 to 2.61)*	Reference	2.00 (1.08 to 3.69)*	1.19 (0.79 to 1.91)
Model 2‡	1.74 (1.21 to 2.49)*	1.78 (1.18 to 2.71)*	Reference	2.19 (1.24 to 3.85)*	1.43 (0.85 to 2.42)
Model 3§	1.68 (1.17 to 2.42)*	1.69 (1.11 to 2.59)*	Reference	2.21 (1.29 to 3.80)*	1.45 (0.85 to 2.48)
Male ≥60 years	n=641	n=449	n=348	n=484	n=179
Model 1†	1.17 (0.85 to 1.62)	1.19 (0.85 to 1.65)	Reference	1.07 (0.66 to 1.73)	0.88 (0.58 to 1.34)
Model 2‡	1.25 (0.90 to 1.73)	1.28 (0.92 to 1.80)	Reference	1.07 (0.66 to 1.74)	0.96 (0.63 to 1.46)
Model 3§	1.24 (0.89 to 1.72)	1.28 (0.91 to 1.80)	Reference	1.07 (0.66 to 1.71)	0.94 (0.62 to 1.43)
Female ≥45 and <60 years	n=728	n=591	n=587	n=595	n=227
Model 1†	1.07 (0.80 to 1.42)	1.24 (0.75 to 2.05)	Reference	1.06 (0.79 to 1.42)	1.34 (0.91 to 1.96)
Model 2‡	1.13 (0.84 to 1.53)	1.17 (0.73 to 1.87)	Reference	1.06 (0.77 to 1.46)	1.57 (1.04 to 2.37)*
Model 3§	1.11 (0.82 to 1.49)	1.16 (0.74 to 1.82)	Reference	1.03 (0.75 to 1.42)	1.55 (1.02 to 2.35)*
Female ≥60 years	n=808	n=381	n=334	n=385	n=176
Model 1†	0.94 (0.62 to 1.43)	0.78 (0.54 to 1.13)	Reference	0.85 (0.59 to 1.23)	0.96 (0.62 to 1.48)
Model 2‡	0.98 (0.62 to 1.57)	0.82 (0.56 to 1.19)	Reference	0.87 (0.61 to 1.25)	1.01 (0.64 to 1.59)
Model 3§	0.97 (0.61 to 1.54)	0.82 (0.56 to 1.21)	Reference	0.88 (0.61 to 1.27)	1.00 (0.62 to 1.59)
Pre-menopause	n=277	n=222	n=255	n=289	n=107
Model 1†	0.98 (0.63 to 1.52)	1.72 (0.68 to 4.40)	Reference	1.02 (0.65 to 1.60)	1.04 (0.57 to 1.92)
Model 2‡	1.08 (0.66 to 1.77)	1.41 (0.63 to 3.14)	Reference	1.10 (0.68 to 1.80)	1.24 (0.65 to 2.38)
Model 3§	1.02 (0.63 to 1.64)	1.32 (0.65 to 2.68)	Reference	1.10 (0.68 to 1.81)	1.24 (0.63 to 2.41)
Post-menopause	n=1245	n=735	n=649	n=680	n=290
Model 1†	1.05 (0.79 to 1.40)	0.86 (0.66 to 1.13)	Reference	0.97 (0.75 to 1.27)	1.20 (0.86 to 1.68)
Model 2‡	1.08 (0.78 to 1.50)	0.88 (0.67 to 1.15)	Reference	0.98 (0.75 to 1.28)	1.31 (0.92 to 1.85)
Model 3§	1.07 (0.77 to 1.48)	0.88 (0.67 to 1.16)	Reference	0.97 (0.74 to 1.27)	1.29 (0.91 to 1.84)

Values are OR (95% CI).

†OR adjusted for age groups and gender.

‡OR adjusted for covariates in model 1 plus BMI categories, smoking, drinking habits, the highest level of education, marital status, region of residence, medical insurance, regular siesta.

§OR adjusted for covariates in model 2 plus diabetes status, dyslipidaemia and high-sensitivity C-reactive protein.

*p<0.05.

BMI, body mass index; CHARLS, China Health and Retirement Longitudinal Study; n, number of subjects analysed.

increased possibility of hypertension. Our findings to some extent parallel the results of the National Health Interview Surveys³² and the English Longitudinal Study of Ageing.³³ It should be noted that the positive associations were statistically marginal (OR 1.55, 95% CI 1.02 to 2.35) in 227 middle-aged women with ≥9/night sleep duration, and thus the result should be interpreted with caution because of the limited sample size in the present study.

It has been speculated that women during menopause are particularly vulnerable to psychosocial stress and hormonal turmoil, which can lead to adverse health outcomes including hypertension.^{25 34} However, no significant associations were found in either the pre- or post-menopausal women in our study. It was reported in the Korean Genome and Epidemiology Study (KoGES)³¹ that premenopausal women with short sleep duration were more likely to be hypertensive. In that study, sleep duration was simply categorised into three groups of <5, 5–7 (as reference) and >7 hours/night, and the age of the subjects ranged from 40 to 69 years

with the mean age ~50 years, which is younger than the participants in CHARLS, limiting comparisons between CHARLS and KoGES. Further epidemiological research should be performed focusing on the gender effect, especially the effect of menopausal status in different regions and populations.

Some potential pathophysiological mechanisms support the biological plausibility of short sleep duration being related to hypertension. A study on male workers indicated that sleep deprivation increases sympathetic nervous system activity, leading to increased BP.³⁵ After sleep loss, increased BP is accompanied by vascular dysfunction and inflammatory activation.³⁶ Sleep deprivation is also related to changes in sympathovagal activity, as evidenced by increased catecholamine release and decreased heart rate.^{37 38} Furthermore, short-term partial sleep deprivation is related to altered activity of the hypothalamic–pituitary–adrenal axis and increased levels of cortisol.^{38 39} For the associations between deprived sleep and elevated BP, the corresponding mechanisms on the disparities with respect to gender,

age, populations and genetic backgrounds should be explored in the future.

Although several epidemiological studies have observed significant associations between long sleep durations and hypertension,^{32–40} the mechanisms are still unclear. Gottlieb *et al*⁶ highlighted that long sleepers always performed less physical activity, and inactivity might bring increased risk of hypertension. Uninvolved confounders and casual bias should be noted in the population studies.⁶ We also found that those with longer hours of sleep had higher BMI and drinking frequency in the CHARLS population, so we estimated the associations by different models adjusted for these factors to reduce the confounding effects. In addition, long sleepers might have underlying depression,⁴¹ poor sleep quality⁴² and sleep-disordered breathing.⁴³ These confounding factors probably had limited influence on our results because we excluded participants receiving antidepressants, tranquilizers, sleeping pills or psychiatric or psychological treatment from the data analysis. Further experimental studies on biological mechanisms are required to explain the association between extended sleep and hypertension.

Study limitations

The CHARLS is a large nationally representative and population-based study. We estimated associations between sleep duration and hypertension using models adjusted for different potential confounders. Some limitations of the present study should be noted. First, it was a cross-sectional analysis with self-reported sleep duration, missing data and low response rate. Second, our analysis was based on middle-aged and elderly participants, which may preclude generalisation of our results to younger populations. Third, the study did not explore the relationship between sleep quality and hypertension prevalence. A recent cross-sectional study indicated an association of poor sleep quality with increased risk of hypertension in a community population,¹⁴ and future studies are warranted to validate this association. Fourth, although 78.69% of hypertensive patients in our data were using antihypertensive medications, confounding by medication intake might not exist for the balanced distribution of drug use by sleep duration ($p=0.172$). Besides, the results remained robust among individuals who were not treated with antihypertensive drugs. Last, the true effect size of sleep duration may be overestimated by OR because of the high prevalence of hypertension in the present study. We calculated both OR and PR and observed similar significance levels between the two indices.

CONCLUSIONS

In summary, our data show that associations between sleep duration and prevalent hypertension among middle-aged and elderly Chinese vary by gender and age. Sleep duration of 7–8 hours per night is recommended to avoid an increased likelihood of

hypertension. Further studies are warranted to investigate the mechanisms of the association between long sleep time and hypertension and to confirm the gender and age specificity.

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Contributors JG and GC designed the study. JG, YF and JL analysed and interpreted the data. LZ and QL drafted the manuscript. GC and QL participated in revising the manuscript. All authors approved the final manuscript.

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Competing interests None declared.

Patient consent Obtained.

Ethics approval The original CHARLS was approved by the ethics review committee of Peking University, and all participants gave written informed consent at the time of participation.

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