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Original Article

The association between PSQI score and hypertension in a Chinese rural population: the Henan Rural Cohort Study

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A B S T R A C T

Objectives: This study investigated the association between poor sleep quality and hypertension, and evaluated how the Pittsburgh Sleep Quality Index (PSQI) score correlates with blood pressure and prevalent hypertension.

Methods: A total of 27, 912 participants aged 18–79 years from the Henan Rural Cohort Study were included into the current study. PSQI score was classified as <3, 3-, 6-, ≥9. Multivariate logistic regression models and restricted cubic spline with hypertension as a dependent variable were conducted. A meta-analysis was conducted to validate the result of the cross-sectional study.

Results: Altogether, 6,085 (21.80%) were poor sleepers and 9,056 (32.44%) suffered from hypertension. The odds ratios (*ORs*) (95% confidence intervals (*CIs*)) of participants with sleep quality of 3-, 6-, ≥9 were 1.16(1.07–1.26), 1.35(1.21–1.50) and 1.62 (1.39–1.88) compared to the participants with a score of less than 3 among participants excluding undiagnosed hypertension. *ORs* and 95% *CIs* per 3 increment score were higher for hypertension (1.16, 1.11–1.21) among total population, (1.18, 1.10–1.27) among men and (1.13, 1.08–1.19) among women. Compared to reference, poor sleep quality was associated with a higher odd of hypertension (*OR* 1.09, 95% *CI* 1.01–1.17) for total population, (1.14, 1.00–1.30) for men and (1.04, 0.95–1.13) for women. Moreover, the odds of hypertension were increased with increment of PSQI score after fitting restricted cubic splines (P_{trend} <0.01). The meta-analysis showed that pooled *OR* of hypertension was significantly higher for poor sleepers (1.62, 1.03–2.56, $I^2 = 97.3\%$, $P < 0.001$).

Conclusions: Higher PSQI score was associated with increased odds of prevalent hypertension in both genders. In addition, poorer sleepers might suffer from hypertension.

1. Introduction

Higher blood pressure (BP) is a principal cause of coronary heart disease (CHD) that has become one of the most severe diseases worldwide and in China. A study using data from the 2002 China National Nutrition and Health Survey suggested that the prevalence of hypertension was 20% in men and 17% in women [1]. A recent research of 1.7 million participants in the China Patient-Centered Evaluative Assessment of Cardiac Events (PEACE) Million Persons Project showed that 45% of middle-aged adults suffers from hypertension and most have not received treatment [2]. Another study found that the prevalence of hypertension was higher in rural areas but with lower rates of awareness, treatment, and control of hypertension [3]. A meta-analysis included 178 studies involving over 2,901,464 participants covering 30 provinces of China suggested about 143 million disability-adjusted life years in China were caused by hypertension [4]. It is essential to explore the factors that impact this rapidly growing prevalence.

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It is well known that sleep, which occupies a significant portion of our lives, affects human health. Previous studies have shown that sleep duration is associated with higher risk of mortality [5], type 2 diabetes mellitus [6], and hypertension [7–10]. However, few studies point that sleep quality instead of duration [11,12] may be more significant. Furthermore, previous studies showed that sleep quality was associated with obesity [13] and glucose level [14]. A previous cross-sectional study conducted in northern China showed that poor sleep quality was associated with increased odds of prevalent hypertension among men [15], but not in women. Another research in elderly subjects using data from a sample of Chinese nonagenarians and centenarians demonstrated that there was no association between sleep quality and arterial blood pressure [16].

Although there are findings on the association between sleep quality and hypertension, the concurrence of these findings have been limited by study population and methodological variations. More so, studies that reported the association between Pittsburgh Sleep Quality Index (PSQI) score and hypertension were not found, especially in limited resource settings. Previous studies [17] suggested that lower education was frequently found to be risk factors for poor sleep quality, and insomnia which might occur in rural population different from urban people who may suffer from much more stress from work. Unlike people in city, rural resident may be disturbed by less environmental factors which might have an impact on sleep status. Sleep quality can be measured by the PSQI questionnaire, which consists of 19 items involving seven factor scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping pills, and daytime dysfunction. Every factor scored 0–3 and the total scores range from 0 to 21 [18], and higher scores indicate poorer sleep quality. Therefore, the aim of the current study was to investigate the association between poor sleep quality measured by the well validated PSQI and hypertension, and evaluate how the PSQI score correlates with blood pressure and prevalent hypertension in Chinese rural population. Furthermore, to verify the current results, a meta-analysis on studies was conducted to evaluate the association between poor sleep quality and hypertension.

2. Materials and method

2.1. Study population

The participants were from the Henan Rural Cohort Study which was conducted in Suiping, Yuzhou, Yima, Tongxu and Xinxiang counties of Henan province and registered in Chinese Clinical Trial Register (Registration number: ChiCTR-OOC-15006699). Detailed description of the study design and data collection has been previously published [19,20]. In short, the baseline of the cohort study was conducted from July 2015 to September 2017. Samples were collected by a multistage, stratified cluster sampling method in the general population. First, simple cluster sampling was used to select five varied regions (south, central, north, east, and west) from Henan province. Second, one to three rural townships in each county were selected by the local Centre for Disease Control and Prevention in consideration of the coherence of the residents, population stability, and local medical conditions. Third, permanent residents who were 18–79 years and signed informed consent were selected as the study sample in each administrative unit (rural village) of the selected township. Consequently, a total of 39, 259 adults (15, 490 men and 23, 769 women, aged 18–79 years) participated in the baseline study of Henan cohort.

For the current analysis, a total of 29, 750 individuals completed the survey of PSQI, those missing hypertension (n = 28), night workers (n = 1525) and those with a history of cancer (n = 285) were also excluded. Finally, the study included 27, 912 participants aged 18–79 years.

The protocol of this study was approved by the ethic committee of the Zhengzhou University Life Science Ethics Committee. Informed consent was obtained from all participants.

2.2. Covariates variables

Data for research was collected using face-to-face interviews. Gender, age (continuous variable), smoking status (non-smoker, or current smoker), alcohol consumption (non-drinker, or current drinker), educational levels (primary school or below, junior high school and senior high school or above), consumption of vegetables and fruits, and prevalent medical conditions and use of medication were obtained by a structured questionnaire.

Those who had smoked for half a year or more and one cigarette per day or more were defined as smokers. Participants who consumed alcohol 12 or more times every year were viewed as drinkers. High vegetable and fruit intake were defined as if participants ate no less than 500 g. Moreover, high fat diet was defined as reported intake of meat of live stocks and poultry intake of 75 g or above among participants, and high salt diet was defined by self-reported taste preferences. Physical activity levels were classified into three categories including light, moderate and vigorous referenced to the criterion in the International Physical Activity Questionnaire (IPAQ) [21].

Anthropometric variables were measured in light clothing and without shoes. Two measurements of weight and height were performed for every participant to the nearest 0.1 kg and 0.1 cm separately, on the basis of a standard protocol [22]. Body mass index (BMI) was computed as weight divided by height squared (kg/m^2).

2.3. Sleep variables

Sleep quality of the participants were assessed by the PSQI [18], which is widely used to measure sleep quality and is well validated, reliable and readily completed by most interviewees. A PSQI score of more than 5 yielded a sensitivity of 89.6%; moreover, a specificity of 86.5% is viewed as poor sleep quality. Further, continuous PSQI score was discretized as < 3, 3-, 6-, and ≥ 9 according to the previously published study [15]. Additionally, trained investigators recorded responses to “What time did you usually go to bed and wake up during the past month?” which was used to compute night sleep duration.

2.4. Measurement of blood pressure

Participants were asked to avoid caffeine, exercise, and smoking for at least 30 min before measurement. Blood pressure (BP) measurements were performed after 5-min rest in seated position, with 30-s intervals between measurements [23], using an electronic sphygmomanometer (HEM-770AFuzzy, Omron, Japan). The average of the three measurements from the right arm of every person was applied to the analyses.

2.5. Ascertainment of hypertension

Participants with hypertension were defined as the following standards [24]: (1) systolic blood pressure (SBP) $\geq$ 140 mmHg and/or diastolic blood pressure (DBP) $\geq$90 mmHg; (2) self-reported hypertension diagnosed by physician and current antihypertensive treatment during the last two weeks. Participants reported no hypertension but found hypertensive when measured were considered as undiagnosed hypertension.

2.6. Meta-analysis

A meta-analysis was conducted by pooling previous studies and the effect of current study on association between poor sleep quality and hypertension according to the guideline of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA). A systematic electronic literature search was conducted in PubMed, Web of Science, CNKI (China National Knowledge Infrastructure) and Wanfang databases from inception to Oct 31, 2018 for the following terms: (sleep quality OR PSQI) AND hypertension. The included studies had at least two groups (good sleep quality, poor sleep quality) and hypertension. The exclusion criteria were: (1) studies in special population (eg, aged 80 or older), (2) reviews, (3) editorials, and (4) case-control studies. Data were extracted from the original literatures separately by two investigators and any ambiguity was resolved by discussion in case of disagreement. From all relevant articles, information extracted included title, the name of the first author, year of publication, study design, sample size, range of age of the participants, adjusted factors, criteria of sleep quality, definition of hypertension, and OR (95% CI) for the poor sleep quality category.

2.7. Statistical analysis

The mean and standard deviation (SD) were shown and comparisons between groups were performed using t-test for continuous data. The categorical data were tabulated with frequencies and percentages and chi-square test was computed to compare the difference between groups. The trend between PSQI score and SBP/DBP was explored by multivariable restricted cubic splines with linear regression models. Logistic regression was conducted to identify the association between PSQI score and hypertension on the basis of 3 models. Model 1 was unadjusted. Model 2 was adjusted for age, gender (only in total population) high salt diet, high vegetable and fruit intake, high fat diet, physical activity, marital status, smoking status, drinking status, educational levels, average monthly income, family history of hypertension, night sleep duration, and BMI. To minimize the potential misclassification of hypertension, a landmark analysis was performed excluding patients with hypertension undiagnosed by physician in model 3 (landmark analysis) adjusted as in model 2. To further visually observe association between continuous PSQI score and hypertension, multivariable restricted cubic regression splines with three knots placed at the fifth, 50th and 95th was performed. Additionally, the logistic regression models were fitted to examine the association between poor sleep quality and hypertension with same confounders above. Finally, a meta-analysis was conducted to validate the current result. Discrepancy in the effect size due to heterogeneity in studies was quantified by the I^2 statistic [25]. The fixed effects model was used for homogeneity (or low heterogeneity), and a random effects model was used for substantial heterogeneity ($I^2 > 50\%$). Egger's test was used to assess the publication bias in the process of performing meta-analysis. All statistical analyses were conducted on the SAS V.9.1 (SAS Institute) and R Language software (version 3.5.1). Meta-analysis was performed using STATA software (version 12; StataCorp). A P value < 0.05 (two-sided test) was considered statistically significant in the study.

3. Results

3.1. Basic characteristics

Table 1 presents the main characteristics of the participants by gender. Among the 27, 912 participants, the mean (SD) age was 55.96 (12.22) years, 11, 167 (40.01%) were men, 6085 (21.80%) were poor sleepers and 9, 056 (32.44%) suffered from hypertension. Participants with hypertension tend to be older, more likely to have a lower education and income, lower consumption of fruits and vegetables and higher salt intake, physically inactive, and have a higher BMI. Similar results can be observed among men and women.

Table 1
Demographic characteristics of participants by gender.

	Total			Men			Women		
	Normotensive	Hypertension	*P*	Normotensive	Hypertension	*P*	Normotensive	Hypertension	*P*
N	18,856	9056		7549	3618		11,307	5438	
Age (year), mean ± SD	53.58 ± 12.49	60.92 ± 9.95	<0.001	55.76 ± 12.45	60.19 ± 10.88	<0.001	52.13 ± 12.29	61.40 ± 9.25	<0.001
Married/cohabitation, n (%)	17,165 (91.03)	7914 (87.39)	<0.001	6788 (89.92)	3253 (89.91)	0.990	10,377 (91.78)	4661 (85.71)	<0.001
Educational levels, n (%)			<0.001			0.023			<0.001
Primary school or below	7900 (41.90)	4869 (53.77)		2562 (33.94)	1311 (36.24)		5338 (47.21)	3558 (65.43)	
Junior high school	7667 (40.66)	3010 (33.24)		3454 (45.75)	1561 (43.15)		4213 (37.26)	1449 (26.65)	
Senior high school or above	3289 (17.44)	1177 (13.00)		1533 (20.31)	746 (20.62)		1756 (15.53)	431 (7.93)	
Average income per month, n (%)			<0.001			0.004			<0.001
<500 RMB	6640 (35.21)	3711 (40.98)		2819 (37.34)	1436 (39.69)		3821 (33.79)	2275 (41.84)	
500- RMB	5921 (31.40)	2883 (31.84)		2284 (30.26)	1120 (30.96)		3637 (32.17)	1763 (32.42)	
≥1000 RMB	6295 (33.38)	2462 (27.19)		2446 (32.40)	1062 (29.35)		3849 (34.04)	1400 (25.74)	
Current smoker, n (%)	3963 (21.02)	1476 (16.30)	<0.001	3931 (52.07)	1461 (40.38)	<0.001	32 (0.28)	15 (0.28)	0.935
Current drinker, n (%)	3176 (16.84)	1510 (16.67)	0.723	2916 (38.63)	1447 (39.99)	0.166	260 (2.30)	63 (1.16)	<0.001
High vegetable and fruit intake, n (%)	9747 (51.69)	3779 (41.73)	<0.001	3912 (51.82)	1533 (42.38)	<0.001	5835 (51.61)	2246 (41.30)	<0.001
High salt diet, n (%)	2930 (15.56)	1499 (16.58)	0.028	1275 (16.91)	720 (19.94)	<0.001	1655 (14.65)	779 (14.35)	0.601
High fat diet, n (%)	3729 (19.78)	1264 (13.96)	<0.001	1881 (24.92)	724 (20.01)	<0.001	1848 (16.34)	540 (9.93)	<0.001
Physical activity, n (%)			<0.001			<0.001			<0.001
Light	5445 (28.88)	3354 (37.04)		2359 (31.25)	1494 (41.29)		3086 (27.29)	1860 (34.20)	
Moderate	7329 (38.87)	2943 (32.50)		2207 (29.24)	894 (24.71)		5122 (45.30)	2049 (37.68)	
Vigorous	6082 (32.25)	2759 (30.47)		2983 (39.52)	1230 (34.00)		3099 (27.41)	1529 (28.12)	
BMI(kg/m^2), mean ± SD	24.11 ± 3.36	25.97 ± 3.65	<0.001	23.81 ± 3.26	25.72 ± 3.47	<0.001	24.31 ± 3.42	26.13 ± 3.75	<0.001
Night sleep duration(h), mean ± SD	7.68 ± 1.26	7.78 ± 1.32	<0.001	7.67 ± 1.25	7.80 ± 1.32	<0.001	7.69 ± 1.26	7.76 ± 1.32	<0.001
PSQI score, mean ± SD	3.70 ± 2.68	3.98 ± 2.82	<0.001	3.27 ± 2.33	3.37 ± 2.39	0.048	3.98 ± 2.85	4.39 ± 3.01	<0.001
Family history of hypertension, n (%)	2749 (14.58)	2461 (27.18)	<0.001	913 (12.09)	952 (26.31)	<0.001	1836 (16.24)	1509 (27.75)	<0.001
SBP(mmHg), mean ± SD	115.67 ± 12.01	147.01 ± 16.97	<0.001	117.13 ± 11.29	145.71 ± 16.16	<0.001	114.69 ± 12.38	147.88 ± 17.44	<0.001
DBP(mmHg), mean ± SD	72.30 ± 8.22	87.92 ± 10.71	<0.001	73.12 ± 8.37	89.25 ± 10.96	<0.001	71.75 ± 8.07	87.04 ± 10.46	<0.001
Poor sleeper, n (%)	3903 (20.70)	2182 (24.09)	<0.001	1151 (15.25)	590 (16.31)	0.148	2752 (24.34)	1592 (29.28)	<0.001

Abbreviation: SD, standard deviation; BMI, body mass index; PSQI, Pittsburgh Sleep Quality Index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

3.2. Trend between PSQI score and blood pressure levels

To observe the trend between PSQI score and BP, the restricted spline curves created for PSQI score are depicted in Fig. 1. As demonstrated, the trend that measures of SBP elevated with the higher score of PSQI but not significant in model 2 among men. Furthermore, the trend has not changed after excluding the participants used anti-hypertensive medicines which might have an impact on the BP as model 3. The similar trend between PSQI and DBP can be observed.

3.3. Association between sleep quality and hypertension

Table 2 shows the association between sleep quality and the likelihood of hypertension. The *ORs* (95% *CIs*) of participants with PSQI score of 3-, 6-, ≥9 were 1.06 (0.99–1.13), 1.09 (1.00–1.19) and 1.24 (1.09–1.41) compared to the participants with a score of less than three among total population in model 2. After exclusion of undiagnosed hypertension, the associations were still significant in both men and women and the magnitude of associations was slightly increased in model 3. Sleep quality was treated as an ordinal variable by using discretized PSQI score to observe the hypertension odds of per three score increments. For each three score increase in PSQI, *OR* for hypertension increased with 16% (95% *CI* 1.11–1.21) among total population, 18% (95% *CI* 1.10–1.27) among men and 13% (95% *CI* 1.08–1.19) among women in final model. Multivariable restricted cubic regression splines were conducted with three knots placed at the fifth, 50th and 95th to visually explore association between continuous PSQI score and hypertension. The odds of hypertension increased with increment of PSQI score after adjusting potential confounders in model 2, which might suggest the poorer sleep quality, the higher odds of prevalent hypertension. Similar results can be found among subjects in analysis that excludes subjects with undiagnosed hypertension (see Fig.2). The further analysis of every item of PSQI and hypertension was conducted to observe the strength of effect. There is stronger association between sleep disturbances and hypertension in women, habitual sleep efficiency and hypertension in men (See Tables A.1–A.3). In addition, no different association between participants with or without a status of snoring was found (data not shown).

3.4. Association between poor sleep quality and hypertension

Fig. 3 shows the association between poor sleep quality (defined as a PSQI score ≥6) and hypertension. In model 2 poor sleep quality was associated with a higher odd of hypertension (*OR* 1.09, 1.01–1.17) for total population, (1.14, 1.00–1.30) for men and (1.04, 0.95–1.13) for women compared with the reference (<6 score). These associations were slightly enhanced in the population excluding hypertension undiagnosed by physician (model 3).

3.5. Meta-analysis of poor sleep quality and hypertension

To validate the current result, a meta-analysis included previous published literature and current study was conducted. The protocol of study selection and the study designs and participant characteristics are shown in supplementary Fig. A. 1 and Table A. 4, respectively. After screening, four unique studies [15,26–28] were included in the final analyses, which corresponds to14, 270 participants. Compared with good sleepers, poor sleep participants were more likely to suffer from hypertension (*OR* 1.62, 95% *CI* 1.03–2.56, I^2 = 97.3%, P < 0.001) (Fig. 4). No publication bias was detected (Egger's test: 0.635).

4. Discussion

In a large population in Chinese rural area, a positive association between PSQI score and the odds of prevalent hypertension was found in both men and women. Furthermore, poor sleep quality

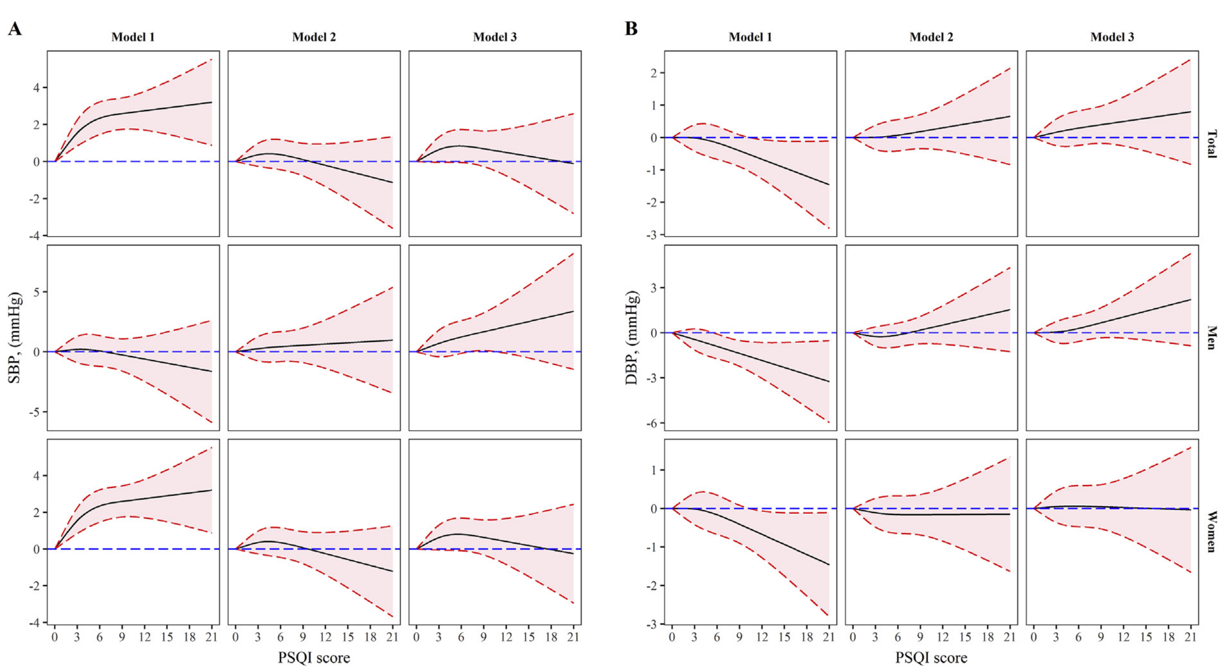

Fig. 1. Mean and 95% confidence intervals of SBP and DBP along with the changes of PSQI score from restricted cubic splines by gender. Model 1: unadjusted; Model 2: adjusted for age, gender (only in total population) high salt diet, high vegetable and fruit intake, high fat diet, physical activity, marital status, smoking status, drinking status, educational levels, average monthly income, family history of hypertension, night sleep duration, BMI; Model 3: adjusted as in model 2 but participants who used anti-hypertensive medicine were excluded from the analysis.

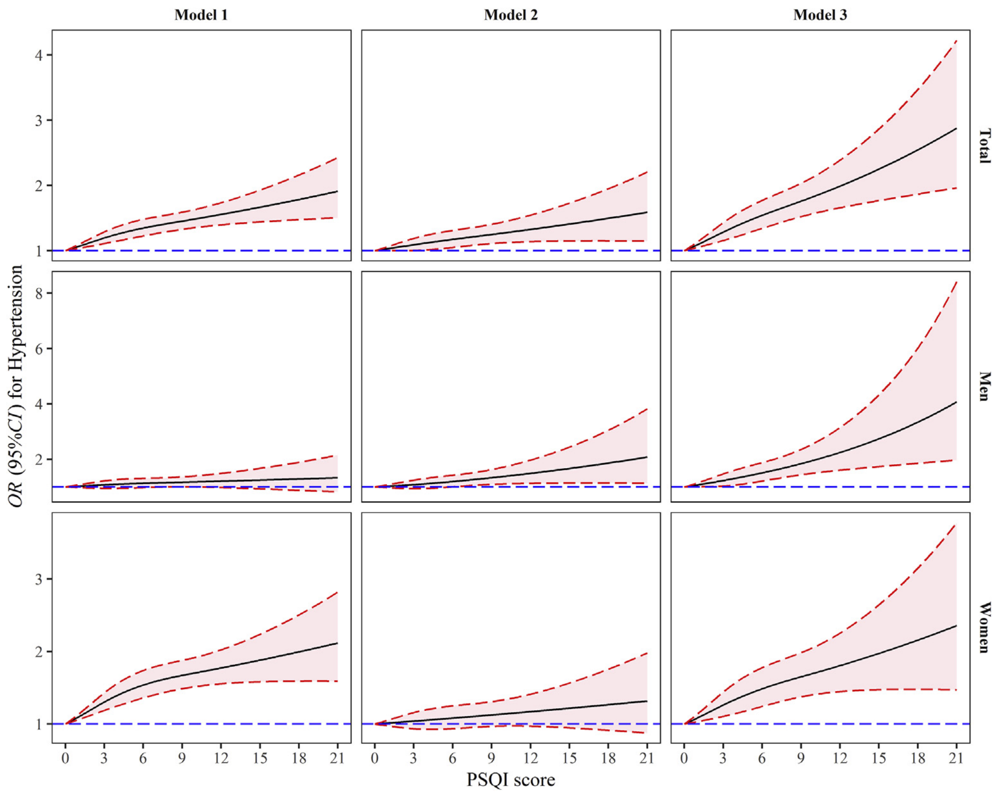

Fig. 2. The association between sleep quality and prevalent hypertension from restricted cubic splines by gender. Model 1: unadjusted; Model 2: adjusted for age, gender (only in total population), high salt diet, high vegetable and fruit intake, high fat diet, physical activity, marital status, smoking status, drinking status, educational levels, average monthly income, family history of hypertension, night sleep duration, BMI; Model 3: adjusted as in model 2 but participant with undiagnosed hypertension were excluded from the analysis.

Table 2
The relationship between multi-categorical PSQI score and prevalent hypertension.

	PSQI score				Per 3 score increment	*P* for trend
	<3	3-	6-	≥9		
Total						
Patients[a]/n	3338/10,898	3536/10,929	1477/4205	705/1880		
Model 1	1.00	1.08 (1.02–1.15)	1.23 (1.14–1.32)	1.36 (1.23–1.50)	1.10 (1.07–1.13)	<0.001
Model 2	1.00	1.06 (0.99–1.13)	1.09 (1.00–1.19)	1.24 (1.09–1.41)	1.06 (1.03–1.10)	0.001
Model 3	1.00	1.16 (1.07–1.26)	1.35 (1.21–1.50)	1.62 (1.39–1.88)	1.16 (1.11–1.21)	<0.001
Men						
Patients[a]/n	1618/5068	1410/4358	435/1297	155/444		
Model 1	1.00	1.02 (0.94–1.11)	1.08 (0.95–1.22)	1.14 (0.93–1.40)	1.04 (0.99–1.09)	0.129
Model 2	1.00	1.08 (0.98–1.19)	1.12 (0.96–1.30)	1.49 (1.17–1.89)	1.10 (1.04–1.16)	0.003
Model 3	1.00	1.13 (1.00–1.28)	1.28 (1.07–1.55)	1.89 (1.42–2.51)	1.18 (1.10–1.27)	<0.001
Women						
Patients[a]/n	1720/5830	2126/6571	1042/2908	550/1436		
Model 1	1.00	1.14 (1.06–1.23)	1.33 (1.21–1.47)	1.48 (1.31–1.67)	1.13 (1.10–1.17)	<0.001
Model 2	1.00	1.02 (0.93–1.12)	1.04 (0.93–1.16)	1.09 (0.93–1.27)	1.02 (0.98–1.07)	0.299
Model 3	1.00	1.17 (1.05–1.31)	1.35 (1.18–1.55)	1.49 (1.25–1.79)	1.13 (1.08–1.19)	<0.001

Model 1: unadjusted; Model 2: adjusted for age, gender (only in total population), high salt diet, high vegetable and fruit intake, high fat diet, physical activity, marital status, smoking status, drinking status, educational levels, average monthly income, family history of hypertension, night sleep duration, BMI; Model 3: adjusted as in model 2 but participants with undiagnosed hypertension were excluded from the analysis.
[a] The number of participants with hypertension.

might be associated with increased likelihood of prevalent hypertension, which was in accordance with the additional meta-analysis in the current study. Similarly, a positive association with PSQI score and hypertension after excluding patients undiagnosed by physician was found. This probably is the first study combining meta-analysis and epidemiological investigation which assesses the association between PSQI score and the odd of hypertension in a large rural population.

China has been a large agricultural country for centuries. It is reported that the rural area (30.8%) faced higher prevalence of hypertension than urban area (26.9%) [4]. Moreover, a large proportion of people with hypertension were without treatment or adequate treatment in rural area. There are few possible reasons for the higher hypertension prevalence in rural than in urban areas in China. First, people in rural region might have a lower income and education than urban people. A previous meta-analysis showed

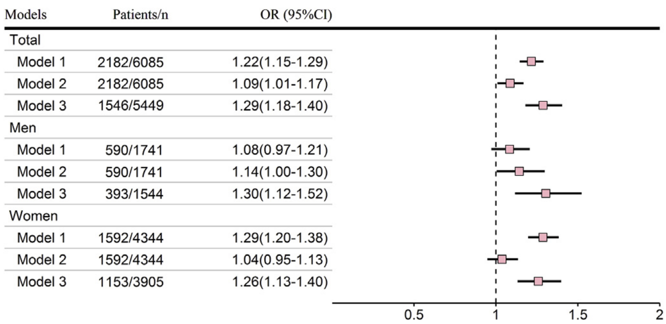

Fig. 3. *OR* for hypertension in Chinese rural population by cut-off points for sleep quality. Data was presented as *OR* and 95% *CI* by sleep quality cut-off points (reference groups <6 scores). Model 1: unadjusted; Model 2: adjusted for age, gender (only in total population), high salt diet, high vegetable and fruit intake, high fat diet, physical activity, marital status, smoking status, drinking status, educational levels, average monthly income, family history of hypertension, night sleep duration, BMI; Model 3: adjusted as in model 2 but participants with undiagnosed hypertension were excluded from the analysis.

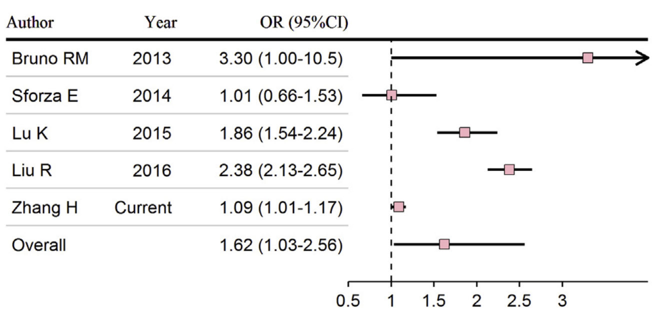

Fig. 4. Forest plot of prevalent hypertension by sleep quality.

that an elevated prevalent hypertension among the lowest socioeconomic status in income, occupation and education compared with the highest socioeconomic status [29]. Second, with the rapid development of economic, changes in lifestyle might have promoted increase in prevalence of hypertension in rural residents in China. Nowadays, more rural people have worked in industries and exposed to unhealthy lifestyles, such as a lower physical activity, a higher intake of salt and fat, and increased work-related stress [30]. Third, there might be a lack of health education, promotion and preventive measures for disease in rural area. Thus, this study was conducted among rural residents, which might be more significant than in citizen.

The current study explored the associations between the PSQI score and BP values as well as hypertension, which were not analyzed in previously published study. First, there is trend the BP values will climb with the increase of PSQI score by visualizing cubic splines. In addition, the current finding suggests that a higher score on PSQI was associated with elevated odds of having hypertension.

This study showed that poor sleep quality was associated with a higher odd of prevalent hypertension, which is consistent with a previous study that reported the association between poor sleep quality and elevated risk of hypertension [28]. Another study conducted in China reported that poor sleep quality was associated with prevalence of hypertension [15]. Furthermore, a study also reported that poor sleep quality measured by the PSQI was related to prevalent hypertension [31]. The association between poor sleep quality and hypertension was further determined in the current study by meta-analysis. However, there were other studies that found no association between poor sleep quality and hypertension [16,27]. One potential reason for this difference is that these studies included participants and patients with various populations. Additionally, night sleep duration was significantly associated with hypertension, which has been demonstrated in many previous studies [10,32–34]. Thus, night sleep duration was adjusted as a confounder in the current study.

The mechanisms behind the association between sleep quality and hypertension are not clear completely. However, there is increasing evidence that poor sleep quality might act as a stressor, activating sympathetic nervous system and hypo-thalamus–pituitary–adrenal axis, causing proinflammatory responses, and leading to endothelial dysfunction [35,36], which increasingly increase blood pressure. The changes of some factors in modern industrialized societies brought perceptible environment changes, which further resulted in metabolically abnormal and arrhythmic of people, consequently interrupting the circadian rhythmicity of BP in high-risk group [16]. Another report also pointed that poor sleep quality was a crucial risk factor for hypertension probably because of elevated activation of the sympathetic nervous system [37].

This study has several strengths. This study thoroughly clarified the association between poor sleep quality and diagnosed hypertension using the Henan Cohort study, a study based on a large population in rural area. Additionally, this is the first study exploring the association between PSQI score and the odd of hypertension in Chinese rural population. Moreover, the association after excluding patients undiagnosed by physician was observed in case of potential misclassification of hypertension. Furthermore, our study demonstrated the association by an additional meta-analysis, which is the first-ever quantitative synthesis of the association so far.

Our study also has some limitations. First, this was a cross-sectional study, and there is the possibility of reverse causality. Second, the data on sleep quality were self-reported, which might introduce inevitably recall bias.

5. Conclusions

A positive association between PSQI score and increased odds of prevalent hypertension and diagnosed hypertension was observed in this large Chinese rural population. Additionally, poor sleep quality might be associated with increased prevalence of hypertension, which suggested changing unhealthy lifestyle might be helpful to lower the likelihood of hypertension and delay disease onset.

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Ethics approval

Ethical approval for this study was obtained from the "Zhengzhou University Life Science Ethics Committee", and written informed consent was obtained from all participants. Ethic approval code: [2015] MEC (S128).

Clinical trial registration

The Henan Rural Cohort Study has been registered at Chinese Clinical Trial Registry (Registration number: ChiCTR-OOC-15006699). http://www.chictr.org.cn/showproj.aspx?proj=11375.

Author contributions

During the research, Chongjian Wang and Ronghai Bie designed the study. Haiqing Zhang, Yuqian Li, Xinyu Zhao, Zhenxing Mao, Tanko Abdulai, Xiaotian Liu, Runqi Tu, Yan Wang, Xinling Qian, Jingjing Jiang, Zhongyan Tian, Zhicheng Luo and Xiaokang Dong directed the collection of the data. Haiqing Zhang and Yuqian Li analyzed the data. Haiqing Zhang and Yuqian Li wrote the manuscript. Tanko Abdulai, Xiaotian Liu and Xinling Qian provided writing assistance. All authors read and approve this version of the article.

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Conflict of interest

None declared.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2019.03.001.

What is already known on this topic?

Previous studies have explored the effect of poor sleep quality on hypertension, but the findings from these studies are inconclusive, as some studies have not shown the significant association between poor sleep quality and hypertension. In addition, no previous studies have examined the association between sleep quality and diagnosed hypertension, especially in rural populations.

What does this study add?

The present study shows that higher Pittsburg Sleep Quality Index (PSQI) score was associated with an increased likelihood of hypertension in this rural population. Furthermore, the significant association was observed after excluding the undiagnosed patients with hypertension in the rural area. Notably, by combining epidemiological research and meta-analysis, the results of this study demonstrated that there is association between poor sleep quality and hypertension.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2019.03.001.

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