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ORIGINAL RESEARCH

Association Between Sleep Quality and Hypertension in Chinese Adults: A Cross-Sectional Analysis in the Tianning Cohort

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Background: Poor sleep quality is becoming very common in a developed society and relates to many health disorders. However, the association between sleep quality and hypertension has not been well studied in Chinese adults.

Methods: Blood pressure was measured and sleep quality was assessed by the Pittsburgh Sleep Quality Index (PSQI) for 5167 participants (mean aged 51±15 years, 41.5% males) in the Tianning Cohort. A logistic regression model was constructed to examine the association between sleep quality, as well as its components, and hypertension, adjusting for age, sex, education level, current smoking, current drinking, physical activity, obesity, glucose, and blood lipids.

Results: After multivariate adjustment, a higher score Of the PSQI was significantly associated with an increased risk of prevalent hypertension (OR=1.03, P=0.018). Compared to participants with normal sleep (the PSQI score <5), those with a poor sleep quality (the PSQI score ≥5) had a 17% increased risk of prevalent hypertension (OR=1.17, P=0.042). Three of the seven components of sleep quality, such as subjective sleep quality (OR=1.17, P=0.001), sleep latency (OR=1.11, P=0.010), and sleep disturbances (OR=1.19, P=0.004), were also significantly associated with prevalent hypertension.

Conclusion: Poor sleep quality is increasingly prevalent in developed societies and may be related to an increased risk of hypertension in Chinese adults. The underlying causality is waiting to be studied.

Keywords: sleep quality, hypertension, Pittsburgh Sleep Quality Index

Introduction

Sleep is an important fundamental need and a determinant for human's optimal health through synchronizing the body's circadian rhythm with a daily cycle.[1,2] Unhealthy sleep patterns, e.g., staying up late and shift work, have been widespread in modern society, affecting approximately 20%~50% of people in the world,[3,4] and this number is suggested to be 38.2% in China.[5] Sleep dysfunction has been associated with a wide range of metabolic disorders, e.g., obesity,[6] diabetes,[7] and dyslipidemia,[8] all are key contributors to hypertension which is a highly prevalent but modifiable risk factor of cardiovascular disease (CVD) - the leading cause of morbidity and mortality all over the world. The daily fluctuations in blood pressure further suggest a potential role of sleep in blood pressure regulation, where blood pressure decreases during normal sleep with autonomic regulation.[9] Indeed, the association between poor sleep quality and hypertension has been extensively studied but with mixed results.[10,11] For example, animal studies in rats found that obstructive sleep apnea (OSA)[12,13] and sleep deprivation[14] resulted in an elevation of blood pressure and hypertension development. Population studies found that patients

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with hypertension were more common to be companied with shortened sleep duration,[15,16] OSA,[17] and poor sleep quality.[18] Most of these studies focused on one or some aspects of sleep, eg, sleep duration or insomnia. The construct of sleep quality likely incorporates multiple aspects eg, subjective sleep quantity, wakefulness, feeling of refreshment upon awakening, daytime sleepiness, and OSA.[19] In fact, not all aspects of sleep quality were believed to play critical roles in hypertension and related complications,[18] so it's urgent to understand their individual contributions to hypertension. However, the contribution of individual aspect of sleep quality to hypertension is still waiting to be studied and whether they could jointly contribute to hypertension is unclear. Here, we used the Pittsburgh Sleep Quality Index (PSQI) to assess seven aspects of sleep quality and examined their associations, individually and jointly, with hypertension in more than five thousand Chinese adults in the Tianning Cohort study.

Methods

Participants

The Tianning Cohort study is an ongoing community-based prospective longitudinal study conducted in an economically developed area of Changzhou city (Tianning District), where the residents maintain a preference for sweet foods, to identify novel risk factors for diabetes and CVD. The study design, survey methods, and laboratory measurements of this study have been reported elsewhere.[20] In brief, a total of 5199 participants aged over 18 years were recruited from 9 communities via cluster random sampling after signing a written informed consent from May to June 2018. After excluding 32 individuals with missing data on sleep quality, 5167 participants were included in the final analysis. The protocols of the Tianning Cohort study were approved by the Ethics Committee of Soochow University (approval No. ECSU-201800051). This study complies with the Declaration of Helsinki.

Assessment of Sleep Quality

Sleep quality was assessed by the PSQI questionnaire administered by trained staff. PSQI was a widely-used and effective self-report questionnaire for assessing sleep quality. It assesses sleep quality and disturbances very comprehensively through 19 individual items designed to assess seven components of sleep quality including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction.[21] The score of each component is equally on a 0–3 scale with a higher score indicating a poorer sleep quality. The total score of the PSQI ranges from 0 to 21 and poor sleep quality was defined as a PSQI score over 5.[22]

Measurement of Blood Pressure

All participants were invited to participate in the physical examination provided between 7:00 and 10:00 in the morning. Blood pressure was measured 3 times (at least 30 seconds between each) by trained staff using a standard mercury sphygmomanometer and a cuff of appropriate size, according to a standard protocol,[23] after the participants had been resting for at least 5 mins in a relaxed, sitting position. The first and fifth Korotkoff sounds were recorded as systolic blood pressure (SBP) and diastolic blood pressure (DBP), respectively. The mean of the 3 measurements was used in statistical analysis. According to the Chinese guidelines for Prevention and treatment of hypertension, hypertension was defined as SBP $\geq$140 mmHg and/or DBP $\geq$90 mmHg or use of antihypertensive medications in the last 2 weeks.[24]

Measurement of Risk Factors of Hypertension

Sociodemographic characteristics including age, sex, and educational level were collected by face-to-face interviews using standard questionnaires in Chinese administered by trained staff. Using the key questions from the Global Adult Tobacco Survey (GATS),[25] smoking status was classified as current, former, and never smoking. Current smoking was defined as having smoked at least 100 cigarettes in the subject's entire life, having smoked cigarettes regularly, and smoking currently. Former smoking was defined as having smoked at least 100 cigarettes in the subject's entire life, having smoked cigarettes regularly in the past, and not smoking currently. Never smoking was defined as never smoking or having smoked fewer than 100 cigarettes in their lifetime. Alcohol consumption was similarly classified as current, former, and never drinking. Current drinking was defined as having consumed alcohol

≥12 times in the past year and drinking currently, former drinking was defined as having stopped drinking alcohol for at least 12 months, and never drinking was defined as never drinking alcohol in their lifetime. Physical activity was assessed by the Global Physical Activity Questionnaire (GPAQ) which collected information on physical activity at work, commuting, and recreational activities as well as sedentary behavior.[26] The measured data were processed according to the GPAQ Analysis Guide, and Metabolic Equivalents minutes (MET-min) per week were calculated and used in data analysis. Body weight and height were measured using a regularly calibrated stadiometer and balance-beam scale with participants wearing light clothing and no shoes. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Waist circumference was measured at 1 cm above the umbilicus. Fasting glucose was detected in overnight fasting blood samples by Hexokinase methods (Siemens Healthcare Diagnostic Inc., Co Antrim, UK). Blood lipids including total cholesterol (TC), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) were measured by the Siemens ADVIA Chemistry XPT system using commercial reagents (Siemens Healthcare Diagnostic Inc., Co Antrim, UK).

Statistical Analysis

A logistic regression of a binary response variable (hypertension) on a continuous variable (the PSQI score) with a sample size of 5167 observations achieves 100% power at a 0.05 significance level to detect a change in probability of hypertension from the value of 0.05 to 0.07 when the PSQI score is increased to one standard deviation above the mean. This change corresponds to an odds ratio of 1.5. An adjustment was made since a multiple regression of the PSQI score on the covariates in the logistic regression obtained an R-Squared of 0.1.[27]

Clinical characteristics of study participants were presented in participants with and without hypertension, respectively. The scores of the PSQI and its components in the two groups of participants were compared using the Wilcoxon rank-sum test. To examine the association between sleep quality and hypertension, we constructed a logistic regression model in which prevalent hypertension (y/n) was the dependent variable and sleep quality (continual PSQI score or categorical poor vs normal) was the independent variable, adjusting for age, sex, education level, cigarette smoking, alcohol consumption, physical activity, BMI, glucose, LDL-C, and HDL-C. The association between the individual component of sleep quality and hypertension was similarly examined. To facilitate data visualization, partial effect plots with spline curves were captured to visualize the impact of the PSQI total score on hypertension by constructing a restricted cubic spline regression model. All statistical analyses were performed using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA). A two-tailed *P* value less than 0.05 was considered statistically significant.

Sensitivity Analysis

To examine whether sex moderates the association between sleep quality and hypertension, we conducted a subgroup analysis by sex. To examine whether cardiovascular disorders modify the association between sleep quality and hypertension, we further excluded participants with coronary heart disease or stroke.

Results

Clinical Characteristics of Study Participants

A total of 5167 participants (mean aged 51±15 years, 41.5% males) were included in the current study. Among them, 2046 individuals (39.6%) were diagnosed with hypertension and 1144 individuals (22.1%) suffered from poor sleep quality. Poor sleep quality was more common in participants with hypertension than in those without (25.3% vs 20.1%, $P<0.001$). Their clinical characteristics were shown in Table 1. As expected, participants with hypertension were more likely to be older and male and have more risk factors, eg, cigarette smoking, alcohol consumption, obesity, blood glucose, and lipids (all $P<0.05$), compared to those without hypertension.

Table 1 The Clinical Characteristics of Study Participants According to Prevalent Hypertension

Characteristics	Hypertension		P
	With	Without	
No. of participants	2046	3121	–
Age, years	60.6±12.2	44.7±14.4	<0.001
Male, n (%)	1019 (49.8)	1125 (36.0)	<0.001
Education, years	9.4±3.8	11.6±3.8	<0.001
Current smoking, n (%)	503 (24.6)	531 (17.0)	<0.001
Current drinking, n (%)	492 (24.0)	469 (15.0)	<0.001
Physical activity, MET-min/week	5120±6766	5236±8816	0.064
Body mass index, kg/m^2	25.2±3.4	23.3±3.6	<0.001
Fasting glucose, mmol/L	5.5±1.6	4.9±1.3	<0.001
Total cholesterol, mmol/L	4.9±0.9	4.7±0.9	<0.001
Triglycerides, mmol/L	2.1±1.3	1.6±1.2	<0.001
LDL cholesterol, mmol/L	2.8±0.8	2.7±0.8	<0.001
HDL cholesterol, mmol/L	1.2±0.3	1.3±0.3	<0.001
History of CVD, n (%)	198 (9.7)	66 (2.1)	<0.001

Notes: Results were expressed with mean ± standard deviation unless otherwise noted.
Abbreviations: MET-min, metabolic equivalents minutes; LDL, low-density lipoprotein; HDL, high-density lipoprotein; CVD, cardiovascular disease.

The PSQI Scores According to Hypertension Status

Participants with hypertension had a significantly higher PSQI score than those without (median: 4 vs 3, *P*<0.001), as illustrated in Figure 1. Table 2 Additionally presented the distributions of the seven components of PSQI according to hypertension status. Compared to participants free of hypertension, those with hypertension were more likely to have a poorer quality of 5 of the 7 PSQI components, such as subjective sleep quality (*P*<0.001), sleep latency (*P*=0.003), habitual sleep efficiency (*P*=0.016), sleep disturbance (*P*<0.001), and use of sleeping medicine (*P*<0.001). These results suggested a probable association between sleep quality and hypertension.

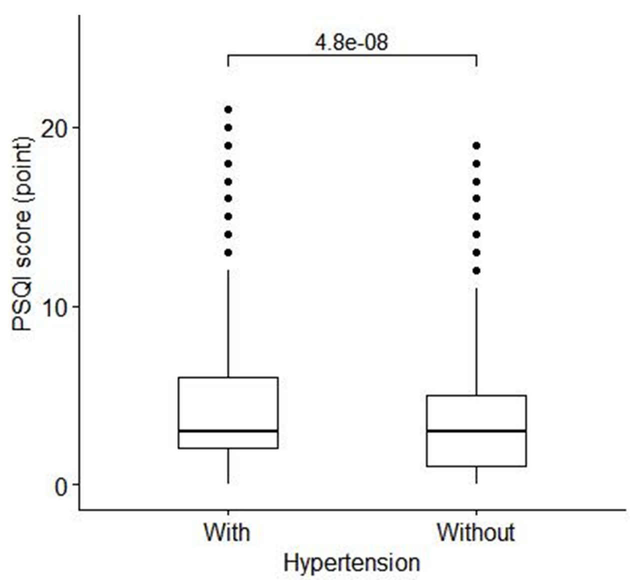

Figure 1 A box plot illustrating the distribution of the total score of Psqi in participants with and without hypertension. The median levels of the total score of Psqi were significantly higher in participants with hypertension than in those without (*P*<0.001). The wiskers indicate 25–75% percentiles.

Table 2 The Distribution of the Seven PSQI Components According to Hypertension

PSQI Components	Hypertension		*P*
	With	Without	
Subjective sleep quality (score)			
Very good (0)	965 (47.2)	1685 (54.0)	<0.001
Fairly good (1)	808 (39.5)	1128 (36.1)	
Fairly bad (2)	226 (11.0)	278 (8.9)	
Very bad (3)	47 (2.3)	30 (1.0)	
Sleep latency (score)			
No difficulty (0)	898 (43.9)	1447 (46.4)	0.003
Mild difficulty (1)	752 (36.8)	1197 (38.4)	
Moderate difficulty (2)	222 (10.9)	301 (9.6)	
Severe difficulty (3)	174 (8.5)	176 (5.6)	
Sleep duration (score)			
>7 hours (0)	841 (41.1)	1340 (42.9)	0.060
6~7 hours (1)	688 (33.6)	1065 (34.2)	
5~6 hours (2)	474 (23.2)	675 (21.6)	
< 5 hours (3)	43 (2.1)	41 (1.3)	
Habitual sleep efficiency (score)			
>85% (0)	1697 (82.9)	2667 (85.5)	0.016
75~84% (1)	106 (5.2)	147 (4.7)	
65~74% (2)	144 (7.0)	163 (5.2)	
< 65% (3)	99 (4.8)	144 (4.6)	
Sleep disturbances (score)			
Never (0)	781 (38.2)	1645 (52.7)	<0.001
Less than once per week (1)	1127 (55.1)	1390 (44.5)	
Once or twice per week (2)	130 (6.4)	83 (2.7)	
Three or more times per week (3)	8 (0.4)	3 (0.1)	
Use of sleeping medication (score)			
Never (0)	1907 (93.2)	3004 (96.3)	<0.001
Less than once per week (1)	43 (2.1)	52 (1.7)	
Once or twice per week (2)	35 (1.7)	26 (0.8)	
Three or more times per week (3)	61 (3.0)	39 (1.2)	
Daytime dysfunction (score)			
Never (0)	1433 (70.0)	2141 (68.6)	0.162
Less than once per week (1)	374 (18.3)	537 (17.2)	
Once or twice per week (2)	149 (7.3)	317 (10.2)	
Three or more times per week (3)	90 (4.7)	126 (4.0)	

Abbreviation: PSQI, Pittsburgh Sleep Quality Index.

Association Between Sleep Quality and Hypertension

We further examined the association between sleep quality assessed by the PSQI scores and prevalent hypertension. As illustrated in Figure 2, a higher score of the PSQI was significantly associated with an increased risk of prevalent hypertension (OR=1.03, P=0.018), after adjusting for age, sex, education level, current smoking, current drinking, physical activity, BMI, glucose, LDL-C, and HDL-C. Compared to participants with normal sleep (the PSQI score <5), those with a poor sleep quality (the PSQI score ≥5) had a 17% increased risk of prevalent hypertension (OR=1.17, P=0.042). Table 3 presents the associations between the seven components of sleep quality and hypertension. After adjusting for covariates, three components of the PSQI, such as subjective sleep quality (OR=1.17, P=0.001), sleep latency (OR=1.11, P=0.010), and sleep disturbances (OR=1.19, P=0.004), were significantly associated with prevalent hypertension. We failed to find statistically significant associations of other components of sleep quality with prevalent hypertension (all P>0.05).

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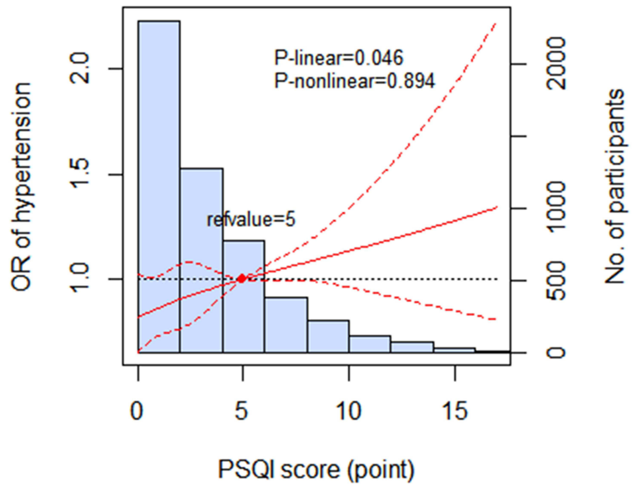

Figure 2 An illustration of the distribution of the total score of the Psqi and its association with hypertension. The blue histograms indicate the number of participants according to the total score of the Psqi. The red lines indicate the spline curve plot illustrating the association between the total score of the Psqi and hypertension with 5 points as the reference. The red dotted lines present the corresponding 95% confidence intervals.

Results of Sensitivity Analysis

Subgroup analysis by sex found that the association between subjective sleep quality and hypertension persisted in both males and females (Supplementary Table S1). No significant group-difference in the magnitude of the association was found, suggesting that the association between sleep quality and hypertension was not influenced a lot by sex. After excluding participants with coronary heart disease or stroke, the association between the PSQI components and hypertension did not change a lot (Supplementary Table S2). These results indicated that the association between sleep quality and hypertension may not be driven by cardiovascular disorders.

Discussion

In the community-based study of Tianning Cohort, we found a significant association between sleep quality assessed by the PSQI questionnaire and prevalent hypertension in Chinese adults. Participants with poor sleep quality were more likely to have hypertension, independent of conventional risk factors including other behaviors and metabolic factors. These findings indicate that poor sleep quality may participate in the development of hypertension through mechanisms beyond metabolic factors.

Sleep disorder, including conditions that affect sleep quality, timing, or duration and impact a person's ability to properly function while they are awake, is becoming a very common unhealthy problem with the rapid economic

Table 3 The Associations of the Seven PSQI Components with Hypertension

PSQI Components	Un-Adjusted		Adjusted*	
	OR† (95%)	*P*	OR† (95%)	*P*
Subjective sleep quality	1.25 (1.16–1.35)	<0.001	1.17 (1.07–1.29)	0.001
Sleep latency	1.13 (1.06–1.20)	<0.001	1.11 (1.02–1.20)	0.010
Sleep duration	1.08 (1.01–1.15)	0.035	1.00 (0.92–1.08)	0.912
Habitual sleep efficiency	1.08 (1.01–1.16)	0.032	1.05 (0.96–1.14)	0.267
Sleep disturbances	1.75 (1.59–1.93)	<0.001	1.19 (1.06–1.34)	0.004
Use of sleeping medication	1.37 (1.22–1.54)	<0.001	1.06 (0.93–1.22)	0.385
Daytime dysfunction	0.95 (0.89–1.02)	0.126	1.08 (0.99–1.18)	0.071

Notes: *Adjusting for age, sex, education level, current smoking, current drinking, physical activity, body mass index, glucose, low- and high-density lipoprotein cholesterol. †Odds ratio of hypertension associated with per point increment in the corresponding scores.
Abbreviation: PSQI, Pittsburgh Sleep Quality Index.

development in China. Data released by HUAWEI Sports Health in 2017 showed that approximately 69.4% of cell phone users have a not very good sleep quality and 23% of young people had a habit of staying up late.[28] Sleep quality is the measurement of how well a person is sleeping – in other words, whether the sleep is restful and restorative. It's very complicated to be measured and not entirely subjective. The PSQI is a widely-used and effective self-report questionnaire for assessing sleep quality. It assesses sleep quality and disturbances very comprehensively through 19 individual items designed to assess seven components of sleep quality including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction.[21] In our study, 22.1% of the participants reported having poor sleep quality assessed by the PSQI questionnaire.

In line with our study, the observed association between poor sleep quality and hypertension has also been found in previous studies. For example, a cross-sectional study including 9404 adults aged 20–93 years in northeastern China found that poor sleep quality defined as the global score of PSQI >5 was significantly associated with an increased risk of prevalent hypertension (OR=2.38, 95% CI:2.13–2.65).[29] A similar association was also observed in other cross-sectional studies of Chinese adults.[30–32] In addition, sleep duration, an important component of sleep quality, has also been associated with hypertension in varied populations.[33–38] Sleep quality represents a complex phenomenon including quantitative and qualitative aspects so it should be assessed comprehensively. Only focusing on sleep duration or any one aspect of sleep quality was insufficient and might be biased to examine the association between sleep quality and hypertension. For example, Bansil et al[18] investigated the role of sleep duration and sleep quality in hypertension development separately in participants of the NHANS, and found that sleep duration alone failed to affect the hypertension prevalence. In our study, we further analyzed whether the individual components of sleep quality were associated with hypertension and found that three components of PSQI including subjective sleep quality, sleep latency, and sleep disturbances were associated with hypertension, while the other components including sleep duration were failed to be significantly associated with hypertension. Although the association between sleep duration and hypertension was not significant either in the NHANS participants,[18] many studies[33,36–38] indicated that sleep duration was associated with hypertension. Anyway, each component of PSQI only reflects one aspect of sleep quality. It's better to examine the association between sleep quality and hypertension, both individually and jointly.

Some possible mechanisms underlying the association between poor sleep quality and hypertension were considered. Of these, stimulation of the sympathetic activity plays an important role.[39,40] Additionally, psychosocial stress, inflammation, oxidative stress, and endothelial dysfunction were reported to link sleep disorders with the development and progression of hypertension.[28] Further, a poor sleep quality could predict a significantly increased risk of CVD in the future.[41] As the leading risk factor of CVD, hypertension may mediate the contribution of sleep quality to CVD, although such mediating effect has not been systemically examined. Therefore, sleep quality, as a modifiable factor, may be of great significance in the prevention of hypertension and cardiovascular complications.

Some limitations should be mentioned in our study. First, this is a cross-sectional study. The causality of the association between poor sleep quality and hypertension cannot be established. Second, although we used unselected sample, the participants in the Tianning Cohort were of the Han ethnicity and could not represent other ethnic populations. The generalizability of our results should be taken cautiously. Third, only self-reported questionnaires were used to assess sleep quality. Possible misclassification and recall bias might exist and influent our results. Fourth, some sleep-related breathing disorders such as insomnia and obstructive sleep apnea have been associated with hypertension and may influent the association between sleep quality and hypertension. We did not obtain such data and the influence of sleep-related breathing disorders on our results can not be prevented.

In summary, hypertension and poor sleep quality are becoming serious health problems in Chinese adults. Participants with poor sleep quality were more likely to have elevated blood pressure and hypertension. Although we can not establish the causality, sleep quality should have to be monitored and under Control for adults to improve the prevention and management of hypertension, as well as other cardiovascular disorders.

Data Sharing Statement

The datasets used during the current study are available from the corresponding author on reasonable request.

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Disclosure

The authors report no conflicts of interest in this work.

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