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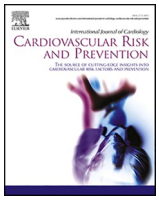

Association of sleep duration with hypertension in young and middle-aged adults: A systematic review and meta-analysis

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ABSTRACT

Background: Hypertension is a primary risk factor for cardiovascular and cerebrovascular diseases. A number of studies have suggested that sleep duration play an important role in the development of hypertension. Hypertension in young and middle-aged individuals is characterized by low awareness and treatment rates, increasing the risk of adverse events. To further elucidate the relationship between sleep duration and hypertension risk in young and middle-aged individuals, we conducted a meta-analysis.

Methods: This study searched PubMed, Embase, and the Cochrane Library from January 2003 to November 5, 2023. Data analysis was performed using STATA 17. Using Q test and I2-statistic, heterogeneity test for the included studies was conducted. Potential small-sample effects were evaluated based on the symmetry of funnel plots, and publication bias in included studies was evaluated using Egger's test.

Results: Data analysis of sleep duration was conducted for 16 studies, which revealed that both long sleep duration (OR, 1.10; 95 % CI, 1.05–1.15) and short sleep duration (RR: 1.10, 95 % CI: 1.05 to 1.15) were associated with hypertension in young and middle-aged individuals, particularly in Asian populations.

Conclusions: This meta-analysis revealed an association between sleep duration (short [<7 h] and long [≥9 h]) and the development of hypertension in young and middle-aged adults, particularly in Asian populations. Sleep is a behavior that can be modified. Clinicians and health professionals should be encouraged to intensify efforts to promote healthy sleep for all and reduce the occurrence of high blood pressure in young and middle-aged individuals.

1. Introduction

Hypertension is a condition marked by a persistent elevation of arterial blood pressure. Although typically asymptomatic, hypertension is a primary risk factor for cardiovascular and cerebrovascular diseases, which can cause severe kidney damage and is closely related to metabolic syndrome [1]. The Global Hypertension Report 2023 estimates a 33 % (age-standardized estimates) global prevalence of hypertension in people aged 30–79 y in 2019. This trend has prompted an increase in the total number of hypertensive patients within the 30–79 y age group, doubling the number of adults with hypertension from 650 million in 1990 to 1.3 billion in 2019 [2]. A cross-sectional study of 900,000 individuals aged 35–49 y showed that 26.2 % (235,000) of young and middle-aged individuals had hypertension [3]. Hypertension in this age group is characterized by low awareness and treatment rates, increasing the risk of adverse events [4]. Research on sleep trends in adults in the United States from 2007 to 2017 revealed a gradual increase in the probability of short sleep duration [5]. In 2022, a large proportion of the Chinese population still slept less than 7 h, with 25.9 % of the population sleeping less than 7 h per night, on average; a widening gap between the shortest and longest sleep durations was observed as well [6]. The relationship between sleep duration (short or long) and negative health outcomes, including cardiovascular and cerebrovascular diseases, metabolic syndrome, and chronic kidney disease has also been reported [7–9]. Shortened or prolonged sleep duration has been found to increase cardiovascular morbidity and mortality in people with type 2 diabetes [10]. The relationship between sleep duration, sleep disturbances, and hypertension has also drawn increasing attention [11–14]. A U-shaped relationship between sleep duration and elevated blood pressure has been demonstrated [15].

Several meta-analyses have recently indicated a correlation between sleep duration and hypertension in adults, with some findings

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demonstrating an association between short and long sleep duration and an increased risk of hypertension [16,17]. A dose–response meta-analysis has shown a 0.3207 % reduction for each 1-h increase in sleep time [18]. Another meta-analysis has associated longer sleep duration with a pervasive risk of hypertension [19]. Nonetheless, these findings lack comprehensiveness, particularly in the absence of a meta-analysis focused on young and middle-aged individuals. Given current research results revealing a trend of hypertension manifesting at increasingly younger ages, we conducted a meta-analysis to further elucidate the relationship between sleep duration and hypertension risk in young and middle-aged individuals.

2. Methods

2.1. Search strategy

This systematic review and meta-analysis were performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) protocol [20].

A systematic search of PubMed, Embase, and the Cochrane Library was conducted between January 1, 2003 and November 5, 2023. The following search terms were used: “Hypertension”、 “Middle Age” and “Sleep Duration”. A combination of keywords and subject headings was also employed in the search strategy.

1) “Prehypertension” or “Pre-Hypertension” or “Pre Hypertension” or “Blood Pressure, High” or “High Blood Pressure” or “Hypertension”
2) “Middle Aged” or “Adult” or “Young Adult”
3) “Sleep Duration” or “Sleep Time” or “Sleep Quantity”

2.2. Inclusion criteria

The inclusion criteria for this study were as follows: (1) eligibility for all cross-sectional, case-control, or cohort design; (2) inclusion of individuals aged 18–65 y in the study population; (3) assessment of the relationship between sleep duration and hypertension, with a baseline of 7 h; and evaluation of hypertension based on criteria such as systolic blood pressure readings ≥140 mmHg or diastolic blood pressure readings ≥90 mmHg, a diagnosis of hypertension, or the use of antihypertensive drugs; (4) reporting of the relative risk (RR) or odds ratio (OR) and 95 % of the association between sleep duration and hypertension risk CI; and (5) inclusion of only one of the studies if the duration and source of study population recruitment overlap by more than 30 % in two or more papers by the same author.

2.3. Exclusion criteria

The exclusion criteria for this study were as follows: (1) laboratory animal studies, (2) case reports, conference abstracts, review papers, editorials, reviews, and small case series ($n < 50$); (3) studies with incomplete reported data and unsearchable full texts, and (5) studies published in languages other than English.

2.4. Data extraction and quality assessment

Data were extracted using a predesigned standard table. The name of the first author, year of publication, geographic region, population source, sample size, study category, type of sleep duration, definition of hypertension, adjusted RR or OR, with a 95 % CI, adjusted factors, and follow-up time were also extracted from prospective cohort studies. Risk of bias was assessed using the National Heart, Lung and Blood Institute quality assessment tools for studies [21]. Literature selection, data extraction, and quality assessment were independently conducted by two reviewers. Inconsistencies were resolved through discussion with a third reviewer.

2.5. Statistical analysis

The association of sleep duration (short [<7 h] and long [≥9 h]) with hypertension in young and middle-aged adults was analyzed. OR or RR with 95 % CI was extracted from the selected papers and used to assess the strength of association between sleep duration and hypertension. The pooled OR (with 95 % CI) of prevalent hypertension and the pooled RR (with 95 % CI) of incident hypertension were separately calculated according to the types of sleep duration (short or long). Using Q test and I^2-statistic, heterogeneity test for the included studies was conducted. For heterogeneity outcome ($P < 0.05$, and/or $I^2 > 50$ %), the random-effects model was utilized for obtaining the pooled results. For homogeneous outcomes ($P \geq 0.05$, and $I^2 \leq 50$ %), the fixed-effects model was applied to pool the effect indexes. Potential small-sample effects were evaluated based on the symmetry of funnel plots, and publication bias in included studies was evaluated using Egger’s test. Subgroup analyses were performed based on sample size and region. After one study was deleted at a time, sensitivity analyses were performed to assess the stability of the results. Statistical analyses were performed using Stata 17.0 software, and the risk assessment of bias was mapped using RStudio.

3. Results

3.1. Characteristics of the included studies

The literature selection process and search results are presented in Fig. 1. In this meta-analysis, 4447 studies were retrieved from the search. These studies included 1217 studies from PubMed, 2941 studies from Embase, and 289 studies from the Cochrane Library). Meanwhile, the following studies were excluded: (i) those that provided no detailed documentation of the OR or RR for the association between sleep duration and hypertension, together with the 95 % CI, and (ii) those in which the reference range of sleep time was not 7 or 7–8 h [22–37].

The main baseline characteristics of the included studies are shown in Table 1. This meta-analysis included 16 studies—3 cohort studies and 13 cross-sectional studies—published between 2007 and 2022. The 16 included studies were geographically distributed as follows: China (11), the United States (2), South Korea (1), Japan (1), and Iran (1). The studies defined hypertension based on one or more of the following criteria: (i) systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg; (ii) current use of antihypertensive medications; and (iii) a history of diagnosed hypertension. The adjusting factors for OR and 95 % CI were gender, income, smoking, alcohol consumption, education level, physical activity, marital status, family history, body mass index (BMI), waist-to-hip ratio, and disease history.

3.2. Risk of bias and sensitivity analyses

Risk of bias assessment in the cross-sectional studies included design limitations, such as ensuring the exposure predated the measured outcome, allowing an appropriate time frame to determine an effect and repeating exposure measurements. Eight studies failed to measure key potential confounding variables and did not adjust statistically for their impact on the relationship between exposure(s) and outcome(s). Fig. 2 encapsulates the risk of bias assessment.

Captions: a–p[22–37]; A. Was the research question or objective in this paper clearly stated? B. Was the study population specified and defined? C. Was the participation rate of eligible persons at least 50 %? D. Were all the subjects selected or recruited from the same or similar populations (including the same period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants? E. Were a sample size justification, power description, or variance and effect estimates provided? F. Were the exposure(s) of interest measured before the outcome(s) being measured for the analyses in this paper? G. Was the timeframe sufficient so that an association

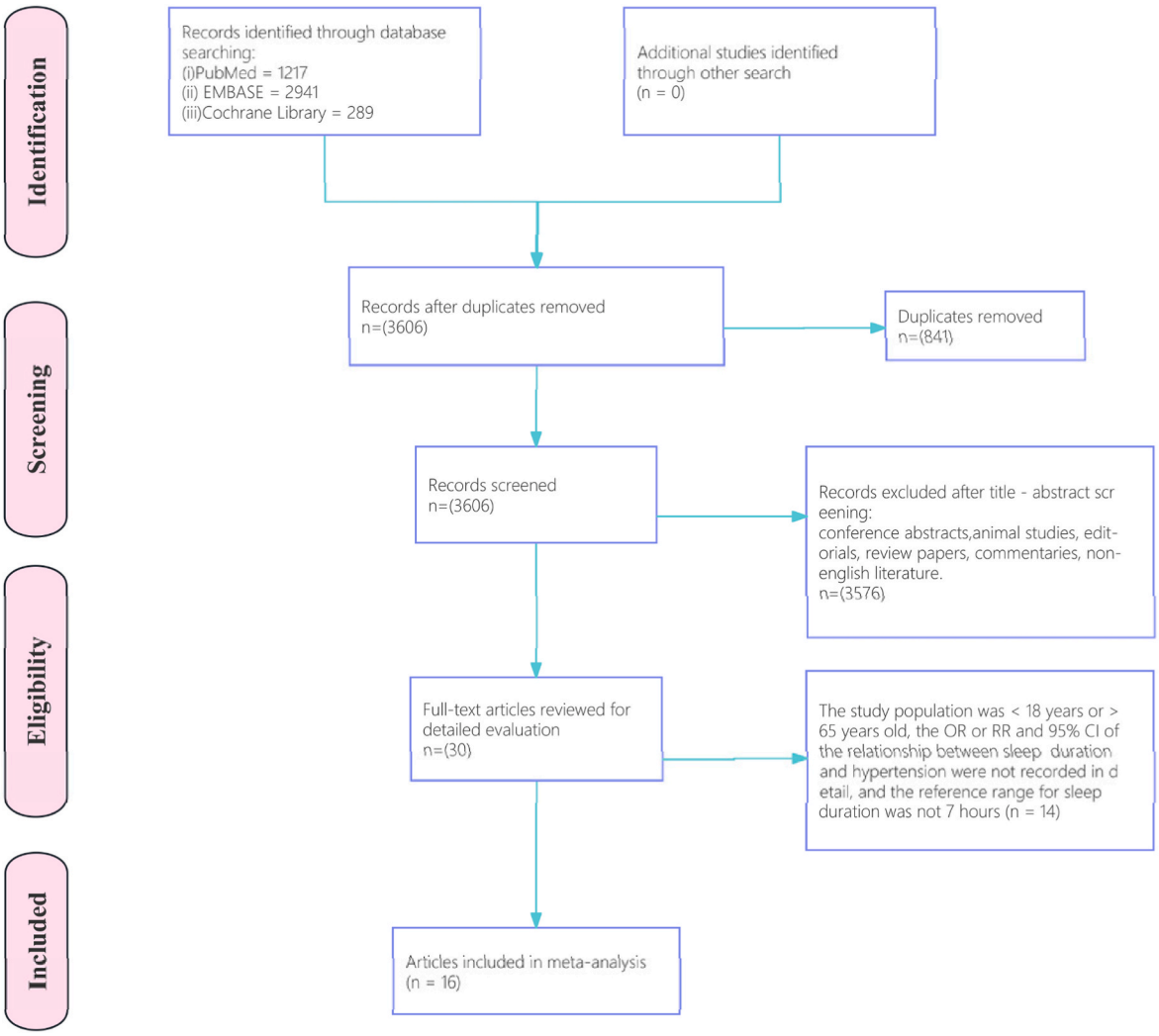

Fig. 1. PRISMA flow diagram of the included studies.

between exposure and outcome, if it existed, could be reasonably expected? H. For exposures that can vary in amount or level, did the study examine different levels of exposure in relation to the outcome (e.g., categories of exposure or exposure measured as a continuous variable)? I. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? J. Was the exposure(s) assessed more than once over time? K. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? L. Were the outcome assessors blinded to the exposure status of participants? M. Was the loss to follow-up after baseline 20 % or less? N. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?

3.3. Meta-analysis

3.3.1. Short sleep duration and hypertension (<7 h)

The meta-analysis included 16 studies, comprising 256,185 participants. One study lacked specific participant details. Moreover, this meta-analysis found a significant association between short sleep duration (<7 h) and an increased risk of hypertension (RR: 1.10, 95 % CI: 1.05–1.15). Significant heterogeneity was found among studies (I2: 61.6 %, P: 0.00). The symmetry of the funnel plot (Fig. 3) and Egger's test (P = 0.094) suggested the absence of publication bias. Forest plot results are presented in Fig. 4(a). Sensitivity analysis (Fig. 5(a)) showed no statistical significance in the pooled results when one study was excluded at a time, exhibiting consistency with the original findings and stability of results. Subgroup analysis based on sample size and region of publication showed a significant association between short sleep duration and the risk of hypertension for studies conducted in Asia (RR: 1.105, 95%CI: 1.048–1.165) and those with a sample size <20000 (RR: 1.173, 95%CI: 1.076–1.279)(Table 2).

3.3.2. Long sleep duration and hypertension(≥9 h)

The meta-analysis included 10 studies involving 224825 participants. No association was determined between long sleep duration (≥9 h) and an increased risk of hypertension (RR: 1.07, 95 % CI: 0.99–1.16). Clear heterogeneity was found between studies (I2: 57.9 %, P: 0.001), but no publication bias was indicated (P: 0.733). Sensitivity analysis revealed that the exclusion of the study by Yunqi Guan (2019) [26] yielded results inconsistent with the original pooled results, resulting in instability. This inconsistency suggested that Yunqi Guan (2019) [26] was the source of heterogeneity in the study of long sleep duration and hypertension risk. Thus, further analysis excluding this study determined a significant association between long sleep duration (≥9 h) and an increased risk of hypertension (OR: 1.10, 95%CI: 1.05–1.15)). No heterogeneity was found between studies (I2: 30.4 %, P: 0.084). The forest plot results are presented in Fig. 4(b). The sensitivity analysis exhibited stability (Fig. 5(b)). Excluding one study at a time led to

Table 1
The characteristics of the included studie (157 line).

Author	Year	Country	Study Design	Sample size	follow-up	Sleep Duration Categories	Sleep duration assessment	Hypertension Criteria	Hypertension assessment	OR(95%CI)	Adjusted
Q Song	2016	China	prospective cohort study	28696	3.98 years	Referent:7 h Short: <7 h Long:⩾ 9 h	Questionnaire	Systolic blood pressure of ⩾ 140 mm Hg, diastolic blood pressure ⩾ 90 mm Hg and/or use of antihypertensive drugs during the follow-up period.	Measurement	⩽5h 1.02 (1.11,1.21) 6h 1.02 (0.96,1.08) 7h 1.00 (Reference) ⩾9h 0.83 (0.97,1.13)	Adjusted for age, gender, resting heart rate, body mass index, smoking, alcohol drinking, physical activity, salt intake, history of diabetes and hyperlipidemia, and antidiabetic and cholesterol-lowering medication, baseline systolic blood pressure, diastolic blood pressure and family history of hypertension.
Jihye Kim	2010	Korea	cross-sectional study	4515	NR	Referent:7h Short: < 7h Long:≥9h	Questionnaire	Systolic blood pressure (SBP) ≥140 or diastolic blood pressure (DBP) ≥90 mm Hg, or regular use of antihypertensive medication.	Measurement	≤5h 1.314 (1.01, 1.71) 6h 1.058 (0.86,1.31) 7h 1.00 (Reference) ≥9h 1.338 (0.96, 1.86)	Adjusted for gender and obesity, smoking status, alcohol consumption, physical activity, depressive symptoms, diabetes mellitus, and stroke.
Xiaoyu Chang	2022	China	cross-sectional study	42,800	NR	Referent:7h Short: <7h Long:≥9h	Questionnaire	Systolic blood pressure (SBP) ≥140 mmHg and/or diastolic blood pressure (DBP) ≥90 mmHg, or prior physician-diagnosed hypertension in hospitals at the township (community) level or above.	Measurement	30–44years old <6h 1.096 (0.869–1.383) 6h 0.871 (0.719,1.055) 0.975 0.883 1.078 7h 1.00 (Reference) ≥9h 1.097 (0.934–1.288) 45–59 years old <6h 1.052 (0.943–1.175) 6h0.975 (0.883,1.078) 7h 1.00 (Reference) ≥9h 1.246 (1.121–1.385)	Adjusted for age, sex, education level, occupation, marital status, income, tea consumption, smoking status, alcohol intake, MET, sedentary leisure time, fresh fruit consumption, insomnia, sleep snoring, BMI, WC, DM, stroke and CHD
Jamshid Najafian	2019	Iran	cross-sectional study	6525	NR	Referent: 7–8h Short: < 7h Long:≥ 8h	Questionnaire	Systolic blood pressure (SBP) of 140 mmHg or more, diastolic blood pressure (DBP) of 90 mmHg or more, or use of antihypertensive medication.	Measurement	<5h 1.48 (1.19,1.84) 5h–7h 1.08 (0.9,1.29) 7h–8h 1.00 (Reference) ≥8h 0.63 (0.47,0.860)	NR
Yunqi Guan	2019	China	cross-sectional study	43655	NR	Referent:7h Short:<7h Long:≥9 h	Questionnaire	Systolic blood pressure (SBP) ≥140 or diastolic blood pressure (DBP) ≥90 mm Hg, or based on self-reported diagnosis of hypertension in hospitals at the township (community) level hospitals or above and had been	Measurement	<6h 1.20 (1.01,1.43) 6h 1.03 (0.92,1.15) 7h 1.00 (Reference) ≥9h 0.87 (0.78–0.96)	Adjusted for other sociodemographic information in each subgroup such as sex, age migration time, marital status, education level, annual income, inflow area, working time, static behavior time, smoking status, alcohol consumption, red meat intake, vegetable and fruit intake, BMI,

(*continued on next page*)

Table 1 (*continued*)

Author	Year	Country	Study Design	Sample size	follow-up	Sleep Duration Categories	Sleep duration assessment	Hypertension Criteria	Hypertension assessment	OR(95%CI)	Adjusted
								taking medicine in the last 2 weeks.			diabetes, stroke and myocardial infarction.
Hao Zhao	2020	China	cross-sectional study	421	NR	Referent: 7–8h Short: <7h Long: ≥9h	SFQ评估表	Blood pressure of at least 140/90 mmHg, or taking anti-hypertension treatment currently	Measurement	<6h 1.42 (0.31, 6.60) 6h–7h 2.72 (1.18,6.29) 7h–8h 1.00 (Reference) ≥9h 1.12 (0.39, 3.21)	Adjusted for sex, income, smoking, alcohol intake, tea drinking, salt intake, physical activity, family history of hypertension, BMI (body mass index), waist-to-hips ratio, adjusted mutually for other sleep variables including sleep duration, sleep quality, habitual timing of sleep, daytime napping, insomnia frequency, frequency of nighttime waking
Xianming Wu	2016	China	prospective cohort study	NR	2y ears	Referent: 7.0–7.9h Short<7h Long:≥8.0h	Questionnaire	Systolic blood pressure (SBP) of 140 mmHg or greater, diastolic blood pressure (DBP) of 90 mmHg or greater, or current antihypertensive treatment.	Measurement	≤4.9h 3.43 (1.06,11.1) 5.0h–5.9h 2.69 (0.95,5.01) 6.0h–6.9h 0.99 (0.55,1.79) 7.0h–7.9h 1.00 (Reference) ≥8.0h 1.26 (0.55,2.9)	Adjusted for sex, baseline blood pressure, personality, BMI, diabetes mellitus and physical exercise, smoking, drinking, TC, TG, HDL-C, LDL-C, hs-CRP, and UA
Fen Yang	2021	China	cross-sectional study	3040	NR	Referent: 7h–8h Short:<7h Long:>8h	Sleep status Pittsburgh sleep Quality Index (PSQI)	(1) Systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg; (2) Self-reported hypertension diagnosed by a physician and current antihypertensive treatment during the previous two weeks.	Measurement	Men <7h 1.49 (1.00–2.23) 7h–8h 1.00 (Reference) >8h 1.63 (0.58–4.58) Women <7h 1.54 (1.16–2.04) 1.00 (Reference) >8h 1.62 (0.75–3.47)	Adjust factors: age, ethnicity, income and shift work status, length of service.
Kai Lu	2017	China	cross-sectional study	4519	NR	Referent: 7h–8h Short:<7h Long:>8h	Sleep status Pittsburgh sleep Quality Index (PSQI)	SBP (systolic blood pressure) ≥ 140 mmHg and (or) DBP (diastolic blood pressure) ≥ 90 mmHg or current antihypertensive medication.	Measurement	<7h 1.33 (1.13–1.56) 7h–8h 1.00 (Reference) >8h 0.97 (0.66–1.41)	Adjust for age, BMI, TC, TG, FBG, physical activity, smoking, drinking, salt intake, educational level and family income;
Jing Guo	2016	China	cross-sectional study	4901	NR	Referent:7–8h Short: <7h Long:≥9h	Questionnaire	An average systolic blood pressure (SBP)/diastolic blood pressure (DBP) ≥140/90 mm Hg, or currently taking antihypertensive medicines, or previously being diagnosed with hypertension.	Measurement	<6h 1.35 (1.07–1.70)* 6h–7h 1.4 (1.02,1.93) 7h–8h 1.00 (Reference) ≥9h 1.52 (1.08–2.12)*	Adjusted for age groups and gender, BMI categories, smoking, drinking habits, the highest level of education, marital status, residential region, medical insurance, regular siesta, diabetes status, dyslipidaemia and high-sensitivity C-reactive protein.
Francesco P. Cappuccio	2007	America	cross-sectional study	5766	NR	" Referent:7h Short: <7h Long: ≥9h	Questionnaire	Blood pressure ≥140/90 mm Hg or regular use of antihypertensive medications.	Measurement	Men ≤5 h 0.88 (0.63,1.23) 6h 0.86	Adjusted for age and employment, alcohol consumption, smoking, physical activity, BMI, SF-36 mental, SF-36

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Table 1 (*continued*)

Author	Year	Country	Study Design	Sample size	follow-up	Sleep Duration Categories	Sleep duration assessment	Hypertension Criteria	Hypertension assessment	OR(95%CI)	Adjusted
										(0.72,1.03) 7 h 1.00 (Reference) ≥9 h 0.92 (0.44,1.92) Women ≤5 h 1.72 (1.07,2.75) 6h 0.92 (0.67,1.28) 7 h 1.00 (Reference) ≥9 h 0.70 (0.21,2.37)	physical, depression cases, hypnotics use, and CVD drugs.
Haiqing Zhang	2019	China	cross-sectional study	20,630	NR	Referent:7h Short: <7h Long: >9h	Sleep status Pittsburgh sleep Quality Index (PSQI)	(i) Systolic BP ≥ 140 mmHg and/or diastolic blood pressure ≤90 mmHg and (ii) Self-reported hypertension diagnosed by a physician and current use of anti-hypertensive medicines. People who reported no hypertension but found hypertensive when measured were defined as undiagnosed hypertension.	Measurement	Men <5h 1.08 (0.68–1.72) 5h 1.05 (0.80–1.37) 6h 0.82 (0.69,0.97) 7h 1.00 (Reference) 9h 0.99 (0.78–1.25) >10 h 1.57 (1.07–2.30) Women <5h 1.11 (0.73–1.68) 5h 0.88 (0.69–1.13) 6h 0.95 (0.83,1.09) 7h 1.00 (Reference) 9h 1.17 (0.99–1.39) >10 h 1.04 (0.77–1.42)	Adjusted for age, high salt diet, high vegetables and fruits intake, high fat diet, physical activity, marital status, smoking status, drinking status, educational levels, average income per month, BMI, family history of hypertension, napping duration, night sleep duration or sleep initiation time.
Meng Li	2019	China	cross-sectional study	15606	NR	Referent: 7h–8h Short:<7h Long:≥8h	Questionnaire	Systolic blood pressure (SBP) ≥140 mm Hg or diastolic blood pressure (DBP) ≥90 mm Hg or the current use of anti-hypertensive medication	Measurement	18–44 years old <7h 1.24 (1.05–1.46) 7h–8h 1.00 (Reference) ≥8h 0.99 (0.84–1.15) 45–59 years old <7h 1.02 (0.91–1.15) 7h–8h 1.00 (Reference)	Adjusted for age, sex, education, marital status, occupation, income, BMI, smoking, drinking, salt intake, physical exercise,BMI and body mass index.

(*continued on next page*)

Table 1 (*continued*)

Author	Year	Country	Study Design	Sample size	follow-up	Sleep Duration Categories	Sleep duration assessment	Hypertension Criteria	Hypertension assessment	OR(95%CI)	Adjusted
Xun-ming Sun	2016	China	prospective cohort study	4657	4 years	Referent: 7h–8h Short: <7h Long:≥9h	Questionnaire	Systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg or currently having antihypertensive treatment.	Measurement	≥8h 1.03 (0.91–1.17) Women 35–44 years old <6h 1.766 (1.024,2.775) 6h–7h 1.139 (0.825,1.573) 77h–8h 1 (Reference) ≥9h 0.994 (0.749,1.319) Women 45–54 years old <6h 0.795 (0.407,1.552) 6h–7h 1.124 (0.906,1.395) 7h–8h 1 (Reference) ≥9h 1.032 (0.729,1.46) Men35–44 years old <6h 0.981 (0.737,1.306) 6h–7h 0.567 (0.84,1.244) 77h–8h 1 (Reference) ≥9 0.905 (0.733,1.116) Men 45–54 years old <6h 0.825 (0.525,1.295) 6h–7h 0.666 (0.901,1.22) 7h–8h 1 (Reference) ≥9h 0.908 (0.679,1.215)	NR
James E. Gangwisch	2016	America	cross-sectional study	68,784	NR	Referent:7h Short: <7h Long: ≥9h	Questionnaire	Be diagnosed with Hypertension.	Self-report	≤5h 1.2 (1.11,1.3) 6h 1.09 (1.04,1.15) 7h 1.00 (Reference) ≥9h 1.07 (0.98,1.17)	Adjusted for age, diabetes, hypercholesterolemia, body mass index, race, Hispanic ethnicity, menopause, smoking, physical activity, alcohol, caffeine, Dietary Approaches to Stop Hypertension diet, aspirin, acetaminophen, nonaspirin Non-Steroidal Anti-Inflammatory Drugs, family hypertension history, snoring, and shift work.

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Table 1 (*continued*)

Author	Year	Country	Study Design	Sample size	follow-up	Sleep Duration Categories	Sleep duration assessment	Hypertension Criteria	Hypertension assessment	OR(95%CI)	Adjusted
Hiroki Satoh	2013	Japan	cross-sectional study	1670	NR	Referent: 7h–8h Short: <7h Long: >8h	Questionnaire	Systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg at their health examination.	Measurement	<6h 2.43 (1.40–4.20) 6h–7h 1.27 (0.81,1.99) 7h–8h 1.00 (Reference) >8h 2.28 (1.31–3.95)	Adjusted for age, body mass index, smoking, alcohol, exercise, family history of hypertension, diabetes mellitus, dyslipidemia, total cholesterol, triglyceride, HDL-cholesterol, and glucose.

NOTE: NR:No report; OR:Odds Ratio; CI: Confidence interval.

Fig. 2. Assessment of risk of bias.

Fig. 3. Assessment of publication bias by funnel plot (a) < 7 h vs.7 h (b) ≥9 h vs. 7 h.

NOTE: CI: Confidence interval; †: Men; ‡: Women.

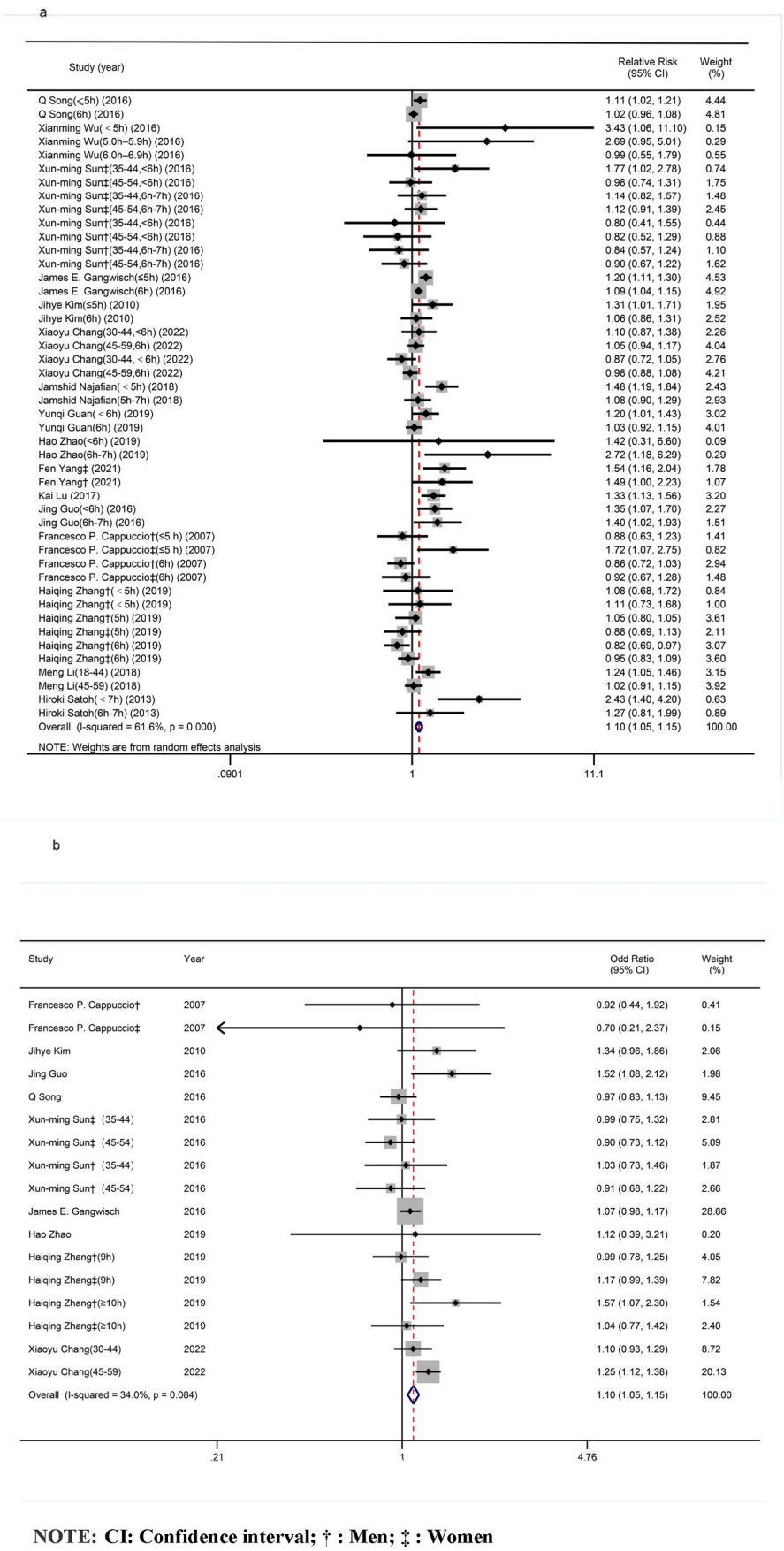
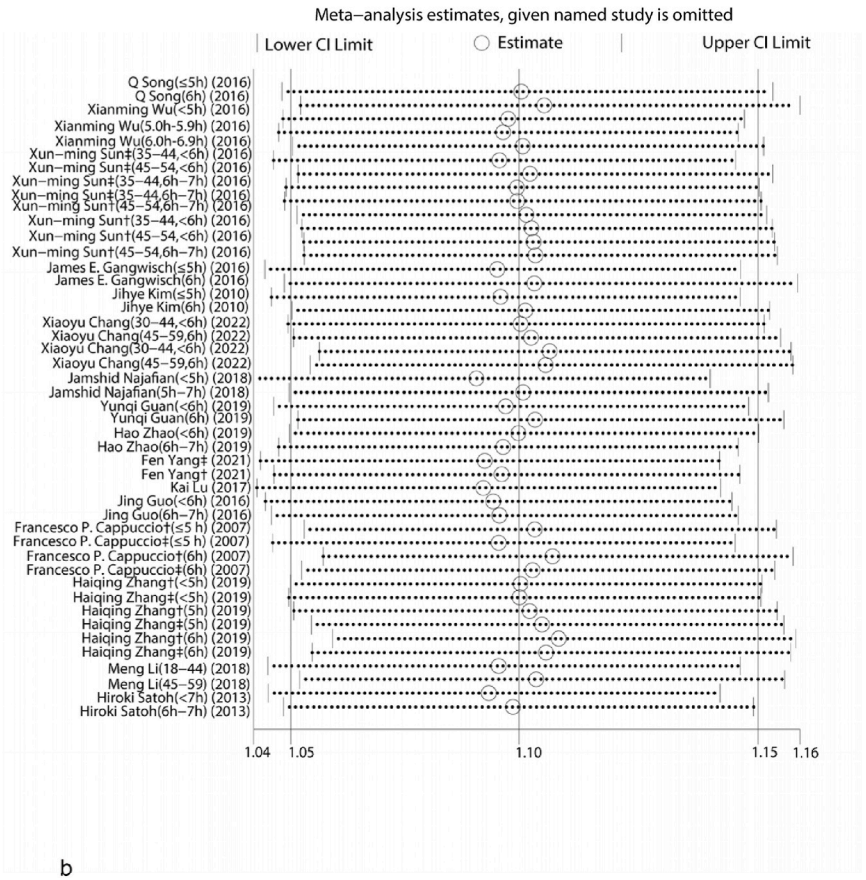


Fig. 4. Forest plots of the association between sleep duration and hypertension risk in young and middle-aged adults (a) < 7 h vs.7 h (b) ≥9 h vs.7 h. NOTE: †: Men; ‡: Women.

a



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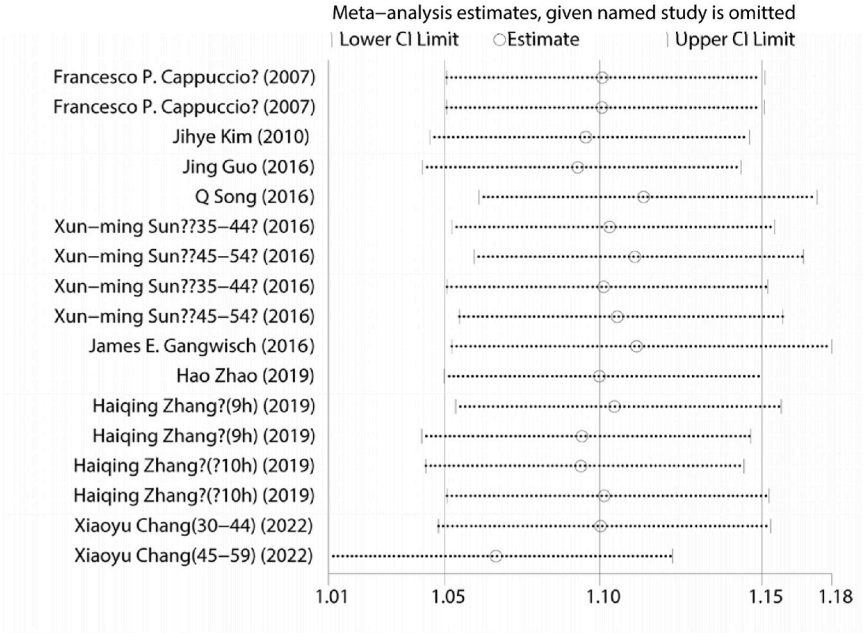

NOTE: † : Men; ‡ : Women

Fig. 5. Sensitivity analysis of included studies (a) < 7 h vs.7 h (b) ≥9 h vs.7 h.

Table 2
Pooled OR and 95 % CIs for the association between sleep duration and hypertension risk.

Subgroups	No. of studies	OR	95 % CI
Short sleep			
All	16	1.10	1.05–1.15
Sample size			
<20000	10	1.173	1.076–1.279
20000–40000	2	1.002	0.935–1.074
>40000	3	1.068	1.003–1.137
Region			
Asia	14	1.105	1.048–1.165
America	2	1.06	0.942–1.192
Long sleep			
All	9	1.10	1.05–1.15
Sample size			
<20000	4	1.037	0.924–1.163
20000–40000	3	1.069	0.973–1.175
>40000	2	1.133	1.064–1.206
Region			
Asia	2	1.065	0.976–1.163
America	7	1.114	1.053–1.179

NOTE: OR:Odds Ratio; CI: Confidence interval.

consistency between the pooled results and the original findings, indicating the stability of the results. Further subgroup analysis based on sample size and region of publication indicated a significant association between long sleep duration and the risk of hypertension for studies with a sample size >40,000 (OR: 1.133; 95%CI: 1.064–1.206) and those conducted in Asia (OR: 1.108; 95 % CI: 1.046–1.173)(Table 2).

4. Discussion

The Academy of Sleep Medicine and the Society for Sleep Research advocate that adults strive for 7–9 h of sleep within a period of 24 h [38]. Unhealthy sleep patterns may disrupt blood pressure responses and increase the risk of high blood pressure [39]. Michael Bursztyn et al. observed that both short (<7 h) and long (>9 h) sleep durations increase the overall risk of death from cardiovascular disease, particularly within Asian populations [40]. The results of the current study indicated a statistically significant correlation between sleep duration (short [<7 h] and long [≥9 h]) and hypertension in young and middle-aged adults. This finding confirms the presence of a U-shaped correlation between sleep duration and hypertension in the aforementioned age group.

4.1. Short sleep duration and hypertension

Short sleep duration is associated with high blood pressure in young and middle-aged adults, consistent with previous studies in other age groups. Among other factors, short sleep duration can potentially lead to high blood pressure in young adults. One study showed that shift work increased elevated serum levels of C-reactive protein (CRP), interleukin-6, and tumor necrosis factor. This response can affect blood pressure in young and middle-aged adults, as well as cause shortened sleep duration and disrupted rhythms [41]. Increased levels of inflammatory cytokines, such as CRP and interleukin-6, can increase sympathetic nervous system activity, thereby exacerbating the stress response of the hypothalamic–pituitary–adrenal axis [42,43]. Disrupting circadian rhythms can lead to vascular dysfunction and increased oxidative stress [44]. Short-term sleep deprivation also leads to a shortened resting period of cortisol secretion and a reduced clearance of free cortisol, resulting in elevated cortisol and blood pressure levels [45]. In a study by Coronary Artery Risk Development in Young Adults, each hour of reduced sleep duration was associated with a 37 % increased risk of hypertension after adjusting for age, sex, and race [46]. Notably, sleep duration is an important factor in major depressive disorder [47]. A large cohort study of a relatively young population found that both short sleep duration and poor sleep quality were associated with depression. Moreover, risk factors for depression, such as smoking, alcohol consumption, and low physical activity, were prevalent among individuals with short sleep [48]. These risk factors may interact with sleep deprivation to directly or indirectly increase the incidence of hypertension in young and middle-aged adults.

4.2. Long sleep duration and hypertension

The potential mechanism linking long sleep duration and hypertension has not been elucidated and can be attributed to several factors. First, prolonged sleep duration can lead to disrupted circadian rhythms within 24 h, including sleep–wake cycles, imbalanced internal and external biological clocks, and asynchronous central and peripheral biological clocks in tissues involved in blood pressure control, resulting in elevated blood pressure [49]. Second, individuals with sleep disorders, such as sleep apnea, may inadvertently have longer sleep durations as they extend their sleep to compensate for their disrupted sleep [50]. Third, longer sleep duration is also associated with large increases in pulse wave velocity and blood pressure variability (BPV). This link suggests that arterial stiffness and BPV are involved in the association between sleep duration and cardiovascular disease (CVD) [51]. In addition, recognized risk factors for hypertension (such as depression, diabetes, obesity, other cardiovascular diseases, and poor lifestyle) and socioeconomic differences may contribute to longer sleep duration, which is often overlooked in studies [52]. A study of the CHARLS population has revealed a higher body mass index (BMI) and alcohol consumption in individuals with longer sleep duration than other groups [31]. A positive correlation between a higher BMI, prevalence of obesity (BMI ≥30 kg/m^2), and excessive sleep duration (usually defined as ≥ 9 h) is also observed [51]. Notably, in studies involving young and middle-aged individuals, those with prolonged sleep duration (9–10 h per day) gained 1.58 kg more body fat than those with average sleep duration (7–8 h per day). This increase is associated with a 21 % increased risk of obesity (relative to the risk of those with normal sleep duration) [53]. In addition, longer sleep duration may reflect low socioeconomic status, low levels of physical activity, unemployment, and poor health [54,55]. Individuals with extended sleep durations are more susceptible to various stressors, exhibit better coping abilities with negative emotions, and face an increased risk of depression [9].

Over the last three decades, Asia has witnessed the highest increase in average blood pressure levels worldwide [56]. Hypertension awareness, treatment, and control rates are generally lower in Asian countries than in other regions [57]. Hypertension in Asia is primarily attributable to variations in genetic background, diet, lifestyle, and sociodemographic factors [58]. Among the common risk factors shared by most Asian countries are obesity, a sedentary lifestyle, alcohol consumption, high socioeconomic status, high salt intake, diabetes, and smoking [59]. A large study found that Asians tend to have extended sleep durations and sleep later than individuals in Western Europe, North America, and Oceania [60]. Moreover, research suggests that anxiety is one of the primary factors contributing to sleep deprivation in Asians, together with genetics, sociocultural differences, and lifestyle habits.

Survey studies show that 235,000 young and middle-aged people suffer from hypertension, with an overall prevalence of 26.2 %. More than 25 % of patients with hypertension and 26.7 % (62,800) of all patients with hypertension have ISH [3]. Compared with older adults, younger individuals exhibit higher SBP, leading to a heightened incidence of hypertension and an increased burden of CVD in the future [61]. Hypertension in older adults is typically caused by age-related arteriosclerosis and increased peripheral resistance, whereas that in younger individuals is primarily associated with the activation of the sympathetic nervous system, activation of the renin–angiotensin system, and increased cardiac output [62]. β receptor blockers have been demonstrated to effectively treat hypertension and reduce cardiovascular events in young and middle-aged individuals. Angiotension Converting Enzyme Inhibitors (ACEI) and Angiotensin Receptor Blocker

(ARBs) exert antihypertensive and target-organ protective effects. Thus, β receptor blockers and angiotensin-converting enzyme inhibitors or angiotensin receptor antagonists are commonly used by young and middle-aged individuals with hypertension [63,64]. Notably, the incidence of depression in young and middle-aged individuals has risen year by year [65]. Depression has been identified as an independent risk factor for hypertension and is more prevalent in patients with hypertension [66]. Simultaneously, sleep problems and depression exhibit a high association [67].

A large number of patients lack a sufficient understanding of the detrimental effects associated with hypertension, often disregarding the need for treatment when patients manifest no symptoms, or struggle with adhering to long-term treatment. Consequently, awareness, treatment and control rates of hypertension are low in young and middle-aged individuals, increasing the possibility of adverse events [68]. Therefore, young and middle-aged people individuals are suggested to sleep for 7–8 h, improve sleep quality, manage risk factors affecting sleep duration and sleep quality, adopt a healthier lifestyle, follow a low-salt diet, quit smoking, limit alcohol intake, engage in regular exercise for weight control, alleviate mental pressure, maintain psychological balance, and seek professional psychological counseling if necessary. These steps are necessary to reduce the prevalence and progression of hypertension and decrease the occurrence of adverse events.

4.3. Limitations

This study has several limitations. First, while simple self-reported sleep duration may be a current marker of overall satisfaction and quality of life, the data remain relatively inaccurate, and more objectively measured sleep duration data are needed to support the conclusions of the study. Second, this meta-analysis included a limited number of prospective studies, with the majority being cross-sectional studies. Third, the number of eligible studies was inadequate, and other data (gender, prevalence of other related diseases, etc.) crucial for additional subgroup analyses were insufficient. Last, the included studies largely varied, potentially influencing the results. In addition, the exclusion of non-English publications in this study may have resulted in the omission of relevant data.

5. Conclusions

This meta-analysis revealed the association of sleep duration (both short [<7 h] and long [≥9 h]) with an increased risk of hypertension in young and middle-aged individuals, particularly in Asian populations.

CRediT authorship contribution statement

Lei Yang: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Fang-Xiao Hu:** Writing – review & editing, Software, Formal analysis, Data curation, Conceptualization. **Kun Wang:** Visualization, Software, Methodology, Formal analysis, Data curation. **Zhi-Zheng Wang:** Visualization, Software, Methodology. **Jie Yang:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Conceptualization.

Ethical approval

Not applicable.

Data availability statement

Data supporting the findings of this study are available from the corresponding author, Jie Yang, upon reasonable request.

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Declaration of competing of interest

The authors report no conflict of interest.

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