Original Article

Predicted 10-year Cardiovascular Disease Risk and Its Association with Sleep Duration among Adults in Beijing-Tianjin-Hebei Region, China*

WANG Yu Xue[1], ZHANG Li[2], LI Chun Jun[3], QI Xin[3], FAN Ya Qi[1], HE Jiang Shan[1], GUO Pei[1], HU Jia Lin[1], CHEN Shuo[4], NIU Yu Jie[5,6], LIU Feng[4], ZHANG Rong[5,6], LI Qiang[4], MA Shi Tao[5,6], ZHANG Mian Zhi[7,8], HONG Cheng Lin[9], and ZHANG Min Ying[1,#]

1. School of Medicine, Nankai University, Tianjin 300071, China; 2. Tianjin First Central Hospital, Tianjin 300071, China; 3. Tianjin Union Medical Center, Tianjin 300071, China; 4. Beijing Physical Examination Center, Beijing 100021, China; 5. Hebei Key Laboratory of Environment and Human Health, Shijiazhuang 050000, Hebei, China; 6. Department of Occupational Health and Environmental Health, Hebei Medical University, Shijiazhuang 050000, Hebei, China; 7. Dongfang Hospital, Beijing University of Chinese Medicine, Beijing 100071, China; 8. Tianjin Academy of Traditional Chinese Medicine Affiliated Hospital, Tianjin 300120, China; 9. Department of Social Welfare, School of Public Affairs, University of California, Los Angeles 90095, CA, America

Abstract

Objective The study aims to predict 10-year cardiovascular disease (CVD) risk and explore its association with sleep duration among Chinese urban adults.

Methods We analyzed part of the baseline data of a cohort that recruited adults for health screening by cluster sampling. The simplified Pittsburgh Sleep Quality Index (PSQI) and Framingham 10-year risk score (FRS) were used to measure sleep duration and CVD risk. Demographic characteristics, personal history of chronic diseases, lifestyle factors were collected using a questionnaire. Height, weight, total cholesterol (TC), and high-density lipoprotein cholesterol (HDL-C) were also measured. Multiple logistic regression models were performed to explore the association of sleep duration with the predicted CVD risk.

Results We included 31, 135 participants (median age 44 years, 53.02% males) free of CVD, cerebral stroke, and not taking lipid-lowering agents. Overall, 14.05%, and 25.55% of participants were at medium and high predicted CVD risk, respectively. Short sleep was independently associated with increased odds of medium to high risk of predicted 10-year CVD among males (*OR* = 1.10; 95% *CI*: 1.01–1.19) and increased odds of medium to high and high risk of predicted 10-year CVD among females (*OR* = 1.23; 95% *CI*: 1.08–1.40; *OR* = 1.27; 95% *CI*: 1.11–1.44). In contrast, long sleep had no association with cardiovascular risk.

Conclusion A substantial number of adults free of CVD were at high 10-year CVD risk. Short sleep was associated with increased odds of predicted CVD risk.

Key words: Predicted 10-year CVD risk; Framingham risk score; Sleep duration

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#Correspondence should be addressed to ZHANG Min Ying, PhD, Associate Professor, E-mail: zhangminying@nankai.edu.cn, Tel: 86-22-23509918.

Biographical note of the first author: WANG Yu Xue, female, born in 1996, Master's Degree Candidate, majoring in epidemiology.

INTRODUCTION

According to the World Heart Federation, there will be over 5 million premature cardiovascular disease (CVD) deaths among men and 2.8 million among women by 2025[1]. *The Chinese Cardiovascular Health Disease Report 2019* showed around 330 million CVD patients in China[2], and CVD remains the dominant cause of death among Chinese adults[3]. Self-awareness of CVD risk is crucial as it can consequently drive people to take prevention against the risk factors. The American Heart Association, European Association for Cardiovascular Prevention, and *Chinese Guidelines for Cardiovascular Prevention* all recommended using risk scoring tools to predict CVD risk and initiate early and well-targeted interventions to reduce CVD disease burden and deaths[4-7].

The Framingham Heart Study Program developed the Framingham Cardiovascular Risk Score (FRS) based on its cohort[8]. Up to now, FRS has been validated and recommended by CVD prevention guidelines in many countries[9-12]. A study in Australia demonstrated the strong power of FRS in identifying the high-risk CVD populations (AUC > 0.85)[13]. Study across Asian ethnicities (Malaysians, Chinese adults, and Indians) also demonstrated its robust potential to be an alternative approach to stratifying 10-year CVD risks[14].

Optimal sleep duration is crucial for cardiovascular health[15]. Long or short sleep duration may lead to increased BMI and reduced insulin sensitivity[16]. It may also induce multiple inflammatory cytokines, affect glucose and lipid metabolism, and induce or accelerate metabolic disorders such as obesity and type 2 diabetes[16]. It has become increasingly evident that optimal sleep is conducive to address many health risk factors, thus maintaining cardiovascular health. Multiple studies using cohort data or local mortality surveillance data had suggested the associations between sleep duration and CVD prevalence[17-20]. However, little is known about the potential relationship between sleep duration and predicted 10-year CVD risk. To date, only Korea, Iran, the US, and Ghana have undertaken studies on the association between sleep duration and predicted 10-year CVD risk and subsequently demonstrated a correlation[21-24]. China has carried out only one related study among postmenopausal women, and no association was found between sleep duration and predicted 10-year CVD risk[25]. This study aims to predict the 10-year CVD risk and further assess the potential association of sleep duration with the predicted 10-year CVD risk among a large sample of Chinese urban adults free of CVD, cerebral stroke, and not taking lipid-lowering agents.

METHODS

Study Design and Population

This study analyzed part of the baseline data of a Cohort Study on the General Population in the Beijing-Tianjin-Hebei Region, a National Key R&D Program of China. We enrolled attendees at eight medical examination centers for health screening in this region from Jan. 2018 to Jan. 2020. Individuals who met the following criteria were recruited into our study: 1) 18 years or older; 2) voluntarily participated in the survey and signed the informed consent. Individuals were excluded if they 1) were with cognitive impairment, hearing impairment, articulate problems, or severe mental illness that cannot complete the survey; 2) were ever diagnosed with cardiovascular diseases or stroke; 3) were taking lipid-lowering agents.

Trained investigators conducted a questionnaire to collect data including demographic characteristics (age, sex, education level, marital status, and occupation), personal history of chronic diseases (hypertension, diabetes, CVD, stroke, hyperlipidaemia, and the respective medication), sleep duration and quality, smoking, alcohol drinking, physical exercise, and sedentary behaviour. Measurements of height, weight, blood pressure, total cholesterol (TC), and high-density lipoprotein cholesterol (HDL-C) in venous blood were performed by professional medical staff at the medical examination centers.

The study protocol was approved by the ethics review boards of Nankai University (Tianjin, China), Tianjin First Central Hospital (Tianjin, China), Tianjin Union Medical Center (Tianjin, China), Beijing Physical Examination Center (Beijing, China), and Hebei Medical University (Shijiazhuang, China). Written informed consent was obtained from each participant.

Measurement of Sleep Duration

The simplified Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep duration and sleep quality with the questions, “During the past month, what time have you usually gone to bed at night?”, “During the past month, how long has it usually taken you to fall asleep each night?” and “During the past month, what time have you usually gotten up in

the morning?". Based on the responses, we calculated the participants' average daily night sleep duration, then classified the sleep duration into three categories for the analyses: short sleep duration (≤ 6 h per night), optimal sleep duration (7−8 h per night), and long sleep duration (≥ 9 h per night)[26]. The investigators also asked the participants: "What do you think of your sleep quality?" Answer options included excellent, good, bad, and awful. Usage of sleep medicine was collected by the question: "During the past month, have you taken medicine to help you sleep?".

Predicted 10-year Cardiovascular Risk by Framingham Risk Score

We assessed 10-year CVD risk using FRS[27], which was calculated using risk factors including age, sex, TC, HDL-C, smoking, treated/untreated systolic blood pressure, and diabetic status. We excluded those who had been diagnosed with CVD, stroke, and those taking lipid-lowering agents. The Framingham risk groups were defined by calculated FRS: low risk (< 10%), medium risk (10%−20%), and high risk (> 20%)[28].

Clinical and Biochemical Measurements

Blood pressure was measured using a sphygmomanometer (Kenz-AC OSC, Japan) in a sitting position for the right arm after resting for at least 5 minutes. Two readings were taken, 1–2 min apart, and a third measurement was made if the first two differed by more than 5 mmHg. The average of the two or three readings was used. Hypertension was defined using criteria from the 2010 Chinese guidelines for the management of hypertension[29]: systolic blood pressure (SBP) ≥ 140 mmHg and/or diastolic blood pressure (DBP) ≥ 90 mmHg or self-reported history of diagnosed hypertension.

Participants were instructed to fast for ≥ 12 h before blood sampling the following morning. TC and HDL-C were measured using the Hitachi 7600 automated analyzer (Hitachi, Inc., Tokyo, Japan).

Height was measured to the nearest 0.1 (cm), and weight (kg) was measured to the nearest 0.1 (kg) by the professional medical staff of the medical examination centers using the same device (GL-310, Seoul, Korea). Body mass index (BMI) was expressed as body weight (kg) divided by squared body height (m^2). Obesity was defined as BMI ≥ 28 kg/m^2[30].

Collection and Definition of Other Variables

The investigators conducted face-to-face interviews with participants to collect information, including personal history of chronic disease (hypertension, diabetes, and hyperlipidaemia). If the participant reported a positive chronic disease history, further questions were asked regarding the time of diagnosis and respective medication. Participants were also asked if they were currently taking lipid-lowering agents. Alcohol drinking, smoking, physical exercise, and sedentary behaviour were also evaluated in the questionnaire. Participants who reported had been smoking for more than half a year were defined as smokers. In contrast, those who reported having smoked but later quit for a sustained period of a half year or longer by the time of the interview were former smokers. Participants who consume alcohol at least once a week were defined as alcohol drinkers. Those who had quit drinking alcohol for a sustained period of a half year or longer by the time of the interview were drinking abstainers. Sitting longer than 6 h per day was defined as being sedentary. Physical exercise was defined as an exercise once a week or more and for at least half an hour each time.

Statistical Analysis

We used Epidata 3.0 to input and clean the data, SPSS 23.0 software for Windows (IBM, Armonk, NY, USA) for data analysis. Normally distributed continuous variables were described using mean ± standard deviation (SD) and compared using *t*-test for two groups, one-way analysis of variance (ANOVA) for more than two groups when homogeneity of variances was met. Brown and Forsythe's test was used where the homogeneity of variances was violated. Median and quartile were used to describe those not distributed normally and compared using the rank-sum test. Categorical variables were described by rates or percentages, and compared by chi-square test, Fisher's exact test, or rank-based test methods. Principal component analysis and maximum variance method were used to perform multivariate logistic regression after rotation. The regression adjusted for potential confounding factors including age, sex, education, BMI, blood pressure, smoking, diabetes, hypertension, blood lipids, antihypertensive agents, exercise, sedentary behaviour, and sleep quality. Odds ratio (*OR*) and 95% *CI* were estimated for predicted 10-year CVD risk according to sleep duration. Two-side *P*-value < 0.05 was considered statistically significant.

RESULTS

Overall, 33,376 participants completed the

survey. After excluding 1,962 participants with diagnosed cardiovascular disease and 679 currently taking lipid-lowering agents, a total of 31,135 participants were included in the analysis. The participants aged 18 to 97 years with a median of 44 years, and about half were males. A majority were of Han ethnicity (96.01%) and in a current marriage (85.79%). Almost sixty percent (59.03%) finished college or undergraduate education, and 39.64% were professionals. The demographic characteristics of the participants were shown in Table 1.

Overall, 60.21%, 14.05%, and 25.55% of participants were at low, medium, and high predicted 10-year CVD risk, respectively. The high and medium predicted 10-year CVD risk was positively associated with older age, male sex, lower education, smoking, alcohol drinking, poor sleep quality, taking sleep medicine, higher SBP, TC and BMI, obesity, hypertension, and diabetes, but negatively associated with sedentary behaviour (P < 0.001 for all, as shown in Table 2).

Table 1. Demographic characteristics of the study population (n = 31,135)

Variable	Median/Number	IQR/(%)
Age (years)	44	35–56
Male	16,507	53.02
Han ethnicity	29,892	96.01
Marital status		
Unmarried	3,882	12.47
In a current marriage	26,710	85.79
Divorced	336	1.08
Widowed	207	0.66
Highest finished education		
Primary school	474	1.52
Junior school	2,464	7.91
Senior school	4,223	13.56
College or undergraduate	18,379	59.03
Postgraduate or above	5,595	17.97
Occupation		
Worker	3,692	11.86
Peasant	575	1.85
Office worker	8,924	28.66
Service seller	3,043	9.77
Professional technologist	12,342	39.64
Student	94	0.30
Housekeeper	82	0.26
Retired	1,138	3.66
Others	1,245	4.00

The proportions of participants who reported short sleep, optimal and long sleep duration were 11.69%, 75.57%, and 12.74%, respectively (Table 3). Compared with optimal sleep duration, short sleep duration was positively associated with CVD risk factors including age, male sex, lower education, smoking, alcohol drinking, lack of exercise, sedentary behaviour, poor sleep quality, taking sleep medicine, higher SBP, TC, BMI, lower HDL-C, hypertension, diabetes, and obesity. Long sleep duration was positively associated with female sex, better sleep quality, higher HDL-C, but negatively associated with education level, smoking, alcohol drinking, sedentary behaviour, TC, BMI, and obesity. (P < 0.001 for all). The highest mean of BMI, SBP, and TC was observed in the short sleep group. The prevalence of CVD associated basic diseases, including hypertension and diabetes, among participants reporting short sleep was higher than that of participants with optimal sleep duration (P = 0.003; P = 0.014). Both the prevalence of medium-to-high (FRS ≥ 10%) and high CVD risk (FRS ≥ 20%) were higher among short sleepers than among optimal sleepers and long sleepers.

Principal component analysis and maximum variance method were used to perform multivariate logistic regression after rotation (Table 4). Among the total population, after completely adjusting for potential confounding factors (including age, sex, education level, SBP, TC, HDL-C, smoking, drinking, sedentary behaviour, physical exercise, BMI, sleep quality, taking sleep medicine, hypertension, diabetes, taking antihypertensive drugs), short sleep was significantly associated with increased odds of medium to high and high risk of predicted 10-year CVD events (OR = 1.17; 95% CI: 1.07–1.28; OR = 1.16; 95% CI: 1.05–1.28), while long sleep was not associated with the predicted 10-year CVD risk. Sex subgroup analysis showed that after completely adjusting for potential confounding factors, short sleep was associated with increased odds of medium to high risk of predicted 10-year CVD among males (OR = 1.10; 95% CI: 1.01–1.19) and increased odds of medium to high and high risk of predicted 10-year CVD events among females (OR = 1.23; 95% CI: 1.08–1.40; OR = 1.27; 95% CI: 1.11–1.44). Though long sleep was associated with increased high CVD risk among males and decreased high CVD risk among females in the unadjusted model (Model 1), the associations were not statistically significant

Table 2. Selected factors among participants by predicted 10-year cardiovascular disease risk

Variable	Predicted 10-year cardiovascular disease risk			*P*
	Low (*n* = 18,764)	Medium (*n* = 4,376)	High (*n* = 7,995)	
Age (years)	38.67 ± 9.94[a]	56.09 ± 9.81[b]	58.01 ± 12.51[b]	< 0.001
Men, *n* (%)	9,404 (50.12)[a]	3,023 (69.08)[b]	4,080 (51.03)[a]	< 0.001
College or above education, *n* (%)	11,437(60.95)[a]	2,346 (53.61)[b]	4,596 (57.49)[c]	< 0.001
Smoking, *n* (%)	2,598 (13.85)[a]	1,347 (30.78)[b]	2,202 (27.54)[c]	< 0.001
Drinking, *n* (%)	4,266 (22.74)[a]	1,488 (34.00)[b]	2,086 (26.09)[c]	< 0.001
Exercise, *n* (%)	12,619 (67.25)	2,999 (68.53)	5,335 (66.73)	0.121
Sedentary behaviour > 6 h, *n* (%)	9,463 (50.43)[a]	1,748 (39.95)[b]	3,346 (41.85)[c]	< 0.001
Excellent & good sleep quality, *n* (%)	16,737 (89.20)[a]	3,828 (87.48)[b]	7,090 (88.68)[ab]	< 0.002
Taking sleep medicine, *n* (%)	404 (2.15)[a]	148 (3.38)[b]	293 (3.66)[b]	< 0.001
SBP (mmHg)	117.42 ± 14.49[a]	132.94 ± 15.98[b]	131.22 ± 21.50[c]	< 0.001
TC (mg/dL)	84.62 ± 16.27[a]	91.44 ± 17.68[b]	88.98 ± 21.53[c]	0.001
HDL-C (mg/dL)	23.98 ± 5.86[a]	23.28 ± 5.73[b]	24.04 ± 5.88[a]	0.001
BMI	24.09 ± 3.82[a]	25.65 ± 3.48[b]	24.85 ± 3.42[c]	< 0.001
Hypertension, *n* (%)	787 (4.19)[a]	1,207 (27.58)[b]	2,405 (30.08)[c]	< 0.001
Diabetes, *n* (%)	131 (0.70)[a]	320 (7.31)[b]	1,059 (13.25)[c]	< 0.001
Obesity, *n* (%)	2,720 (14.50)[a]	949 (21.69)[b]	1,324 (16.60)[c]	< 0.001

Note. Data were reported as mean (standard deviation) and number (percentage). *P*-values were reported as the results of ANOVA and rank sum test. [a,b,c]Designated according to post hoc analysis. SBP, systolic blood pressure. TC, total cholesterol. HDL-C, high density lipoprotein cholesterol. BMI, body mass index.

Table 3. Conventional risk factors for cardiovascular disease by sleep duration

Variable	Sleep duration			*P*
	≤ 6 h (*n* = 3,640)	7–8 h (*n* = 23,528)	≥ 9 h (*n* = 3,967)	
Age (years)	47.41 ± 12.86[a]	45.90 ± 13.92[b]	45.97 ± 15.59[b]	< 0.001
Men, *n* (%)	2,225 (61.13)[a]	12,468 (52.99)[b]	1,814 (45.73)[c]	< 0.001
College or above education, *n* (%)	2,132 (58.57)[a,b]	13,989 (59.46)[b]	2,258 (56.92)[a]	< 0.001
Smoking, *n* (%)	1,071 (29.42)[a]	4,511 (19.17)[b]	592 (14.92)[c]	< 0.001
Drinking, *n* (%)	1,148 (31.54)[a]	5,868 (24.94)[b]	824 (20.77)[c]	< 0.001
Exercise, *n* (%)	2,298 (63.13)[a]	16,024 (68.11)[b]	2,631 (66.32)[b]	< 0.001
Sedentary behaviour > 6 h, *n* (%)	1,947 (53.49)[a]	11,008 (46.79)[b]	1,702 (42.90)[c]	< 0.001
Excellent & good sleep quality, *n* (%)	3,017 (82.88)[a]	21,034 (89.40)[b]	3,604 (90.85)[c]	< 0.001
SBP (mmHg)	124.62 ± 18.31[a]	122.94 ± 18.06[b]	122.95 ± 18.83[b]	< 0.001
Taking sleep medicine, *n* (%)	150 (4.12)[a]	583 (2.47)[b]	112 (2.82)[b]	< 0.001
TC (mg/dL)	87.67 ± 17.27[a]	86.66 ± 18.33[b]	86.05 ± 17.84[c]	0.001
HDL-C (mg/dL)	23.63 ± 5.86[a]	23.90 ± 5.73[b]	24.13 ± 5.88[c]	0.001
BMI	25.05 ± 3.80[a]	24.47 ± 3.70[b]	24.20 ± 3.72[c]	< 0.001
Hypertension, *n* (%)	575 (15.80)[a]	3,300 (14.03)[b]	524 (13.21)[b]	0.003
Diabetes, *n* (%)	212 (5.82)[a]	1,113 (4.73)[b]	185 (4.66)[b]	0.014
Obesity, *n* (%)	752 (20.66)[a]	3,658 (15.54)[b]	583 (14.70)[c]	< 0.001
FRS ≥ 10%, *n* (%)	633 (17.39)[a]	3,250 (13.81)[b]	493 (12.43)[b]	< 0.001
FRS ≥ 20%, *n* (%)	1,040 (28.57)[a]	5,936 (25.23)[b]	1,019 (25.69)[b]	< 0.001

Note. Data were reported as mean (standard deviation) and number (percentage). *P*-values were reported as the results of ANOVA and rank sum test. [a,b,c]Designated according to post hoc analysis. SBP, systolic blood pressure. TC, total cholesterol. HDL-C, high density lipoprotein cholesterol. BMI, body mass index. FRS, Framingham cardiovascular risk score.

Table 4. Correlations between sleep duration and predicted 10-year CVD risk

Sleep duration (h)	Medium-to-high risk (*n* = 12,371)			High risk (*n* = 7,995)		
	OR	95% *CI*	*P*	*OR*	95% *CI*	*P*
Model 1						
7–8	1					
≤ 6	**1.33**	**1.24–1.43**	**< 0.01**	**1.28**	**1.20–1.36**	**< 0.01**
≥ 9	0.96	0.90–1.03	0.27	1.00	0.95–1.06	0.92
Model 2						
7–8	1					
≤ 6	**1.21**	**1.11–1.33**	**< 0.01**	**1.20**	**1.08–1.32**	**< 0.01**
≥ 9	0.98	0.89–1.08	0.65	0.99	0.89–1.11	0.92
Model 3						
7–8	1					
≤ 6	**1.18**	**1.09–1.29**	**< 0.01**	**1.17**	**1.08–1.29**	**< 0.01**
≥ 9	0.93	0.85–1.02	0.12	0.96	0.87–1.06	0.42
Model 4						
7–8	1					
≤ 6	**1.20**	**1.11–1.30**	**< 0.01**	**1.19**	**1.08–1.30**	**< 0.01**
≥ 9	0.96	0.89–1.04	0.36	0.99	0.91–1.09	0.88
Model 5						
7–8	1					
≤ 6	**1.17**	**1.07–1.28**	**< 0.01**	**1.16**	**1.05–1.28**	**< 0.01**
≥ 9	0.94	0.85–1.02	0.15	0.96	0.87–1.06	0.45
Men (*n*)		7,103			4,080	
Model 1						
7–8	1					
≤ 6	**1.25**	**1.15–1.37**	**< 0.01**	**1.18**	**1.09–1.28**	**< 0.01**
≥ 9	1.03	0.93–1.14	0.55	**1.12**	**1.02–1.22**	**0.01**
Model 2						
7–8	1					
≤ 6	**1.32**	**1.17–1.49**	**< 0.01**	**1.36**	**1.17–1.59**	**< 0.01**
≥ 9	0.95	0.82–1.10	0.48	0.94	0.78–1.13	0.49
Model 3						
7–8	1					
≤ 6	**1.24**	**1.08–1.40**	**0.01**	**1.19**	**1.01–1.41**	**0.04**
≥ 9	**0.83**	**0.72–0.97**	**0.02**	0.88	0.73–1.07	0.19
Model 4						
7–8	1					
≤ 6	**1.14**	**1.02–1.27**	**< 0.01**	1.06	0.92–1.21	0.45
≥ 9	0.96	0.85–1.08	0.50	1.05	0.94–1.23	0.43
Model 5						
7–8	1					
≤ 6	**1.10**	**1.01–1.19**	**< 0.01**	1.05	0.83–1.16	0.47
≥ 9	0.95	0.82–1.09	0.61	1.03	0.91–1.21	0.51

Continued

Sleep duration (h)	Medium-to-high risk (*n* = 12,371)			High risk (*n* = 7,995)		
	OR	95% *CI*	*P*	*OR*	95% *CI*	*P*
Women (*n*)		5,268			3,915	
Model 1						
7–8	1					
≤ 6	**1.38**	**1.23–1.54**	**< 0.01**	**1.41**	**1.29–1.55**	**< 0.01**
≥ 9	0.94	0.85–1.03	0.20	**0.92**	**0.85–1.00**	**0.04**
Model 2						
7–8	1					
≤ 6	**1.22**	**1.07–1.38**	**< 0.01**	**1.25**	**1.09–1.42**	**< 0.01**
≥ 9	0.98	0.87–1.10	0.69	0.98	0.87–1.10	0.73
Model 3						
7–8	1					
≤ 6	**1.26**	**1.11–1.42**	**< 0.01**	**1.29**	**1.13–1.47**	**< 0.01**
≥ 9	0.93	0.83–1.04	0.22	0.93	0.83–1.05	0.24
Model 4						
7–8	1					
≤ 6	**1.29**	**1.14–1.41**	**< 0.01**	**1.33**	**1.17–1.51**	**< 0.01**
≥ 9	0.93	0.83–1.03	0.16	0.92	0.82–1.03	0.15
Model 5						
7–8	1					
≤ 6	**1.23**	**1.08–1.40**	**< 0.01**	**1.27**	**1.11–1.44**	**< 0.01**
≥ 9	0.94	0.84–1.05	0.27	0.93	0.83–1.05	0.28

Note. Model 1 was not adjusted. Model 2 was adjusted for age and gender (except gender-specific models). Model 3 was adjusted for age, gender (except gender-specific models), education level, systolic blood pressure, total cholesterol, high density lipoprotein cholesterol, smoking, drinking, sedentary behaviour, exercise, body mass index, history of hypertension, and diabetes. Model 4 was adjusted for sleep quality and all variables in Model 3. Model 5 was adjusted for taking sleep medicine and all variables in Model 4.

after adjusting for age (Model 2) and all selected potential confounding factors (Model 4).

DISCUSSION

To our best knowledge, the present study is the first to explore the association between sleep duration and the predicted CVD risk and examine the association between sleep duration and the predicted cardiovascular risk among general Chinese adults. We found 60.21%, 14.05%, and 25.55% of participants were at low, medium, and high predicted 10-year CVD risk. Short sleep was associated with the medium-to-high risk of predicted 10-year CVD in men and the medium-to-high and high risk of predicted 10-year CVD events among females. In contrast, long sleep was not found associated with predicted cardiovascular risk in both sexes. These findings help identify adults at risk of CVD and highlight the need for interventions to improve their cardiovascular health.

Previous studies have presented data about sleep duration and cardiovascular diseases[20,31]. Still, few have investigated the association between sleep duration and predicted cardiovascular risk among CVD free adults, especially in Chinese adults. The current study found that short sleep was independently associated with elevated cardiovascular risk. Numerous studies have consistently found that persons with short sleep duration were more likely to have increased cardiovascular risk or mortality[22,24]. Studies found that short sleep could not only increase the risk for insulin resistance, resulting in obesity, type 2 diabetes, and incident cardiovascular disease[17,32], but could also affect sympathetic nervous system

activity and increase blood pressure, and cause a change in ghrelin production, thus leading to the activation of pro-inflammatory pathways[33], and promoted the development of CVD by pro-inflammatory biomarkers including TNF-α, IL-1, IL-6, IL-17, CRP, coagulation molecules, cellular adhesion molecules, and visfatin[34-35]. In addition, we found short sleep duration was positively associated with conventional cardiovascular risk factors, including older age, higher TC and SBP, lower HDL-C, and smoking, which are part of the risk equation. Moreover, we also found short sleep duration was associated with alcohol drinking, sedentary behaviour, obesity, hypertension, and diabetes, which are closely related to CVD events[36-39]. The remaining factors were all contributed to predicted 10-year CVD risk, suggesting that improving cardiovascular health among short sleepers requires a broad-based approach to risk-factor modification, modifiable risk behaviors including smoking, alcohol drinking, and sedentary behaviour should be targeted. Previous studies have demonstrated that smoking is related to various subtypes of sleep disturbances in both sexes[40-44] and short sleep duration is associated with alcohol consumption in adults. Severe alcohol hangovers can reduce total sleep time. Sleep disturbance increases with the number of days of alcohol consumption and the amount of alcohol consumed per drinking session[42-44]. In addition, shorter sleep was associated with increased sedentary time, irrespective of gender, age, education level, and weight status[45-46]. Consequently, predicted 10-year CVD risk could be substantially decreased by tailored behaviour intervention testing on smoking, drinking, and sedentary behaviour.

In our study, though long sleep was associated with increased CVD risk among males and decreased CVD risk among females in the unadjusted model, the associations were not statistically significant after adjusting for age and all selected potential confounding factors. The finding is inconsistent with other studies where long sleep duration was also associated with increased CVD risk[24]. We speculated the inconsistent associations of CVD risk with sleep duration with previous studies could be due to the different study populations and different categorical cutoffs for sleep duration[47-49]. Previous findings showed the relationship between sleep duration and cardiovascular diseases might be affected by instances of underlying disease that caused subjects to sleep more to survive the severe underlying illness[17,50-52]. Studies also suggested that worsening physical condition might be associated with both long sleep duration and mortality. The relationship between long sleep and CVD risk may be confounded by underlying comorbid conditions, poor general health, or depressive symptoms[53]. However, among our study population, compared to individuals with optimal sleep duration, long sleepers were even more likely to be female sex, non-smokers, non-alcohol-drinkers, have better sleep quality, shorter sedentary duration, higher HDL-C, but lower TC and BMI, and free of hypertension and diabetes, which were all known protective factors for CVD and general health. Although these risk factors were all adjusted in the analyses, residual confounding might remain. In addition, compared to the optimal sleepers, long sleepers in our study might have a better physical condition or general health and fewer comorbid conditions, which decreased their cardiovascular risk. There were also studies with consistent findings that only short sleep was associated with cardiovascular risk[54-55]. Despite the strong evidence of abnormal sleep duration as a risk factor for CVD, the biological mechanism is still not thoroughly revealed. Further experimental and epidemiological research is needed to explore the association between sleep duration and CVD risk.

After adjusting for potential confounding factors, sex subgroup analyses found a positive association of short sleep with both medium-to-high and high predicted 10-year CVD risk among women and a positive association between short sleep and medium-to-high predicted 10-year CVD risk among men. In contrast, long sleep was not associated with predicted 10-year CVD risk in either sex. Our findings are partly consistent with an Iranian study where short sleep was associated with predicted CVD risk only among women, but not men[22], suggesting that short sleep on CVD risk is more significant in women than in men. However, a study in Korea showed both short and long sleep had associations with predicted 10-year CVD risk for both sexes[24]. These two studies and our study had a result in common: the proportion of short sleepers with high predicted 10-year CVD risk was greater than that of the optimal sleepers. This conclusion is consistent with the findings of studies among American and Ghanaian adults[21,23]. However, intrinsic variations of samples might result in differences in findings between our research and the above. Sleep durations vary across cultures and countries[56-57], thus alter the associations between sleep profiles and disease risks[58-59]. For example, a study in the US involving

3,942 postmenopausal women showed long sleep might increase the incidence of coronary heart disease[60]. While in China, a study of 4616 postmenopausal women showed neither short nor long sleep was associated with cardiovascular risk[25]. The sex difference in the association between sleep duration and predicted CVD risk varied across countries with different ethnic groups and cultures and should be considered in future interventions.

The strengths of the present study lie in the largest sample ever for this research topic worldwide. Using a large sample, we get a more diverse population on age, occupation, sleep duration, and predicted CVD risk. The sample size is large enough for each subgroup, which guarantees the high reliability of the results. More importantly, data of a large population from the real world are of great significance for understanding CVD risk and further developing preventive strategies. Secondly, most studies on this issue in different countries and China have focused on middle age or older populations for the hypothesis that young adults were of a low CVD risk or free of CVD risk. However, we included 60.5% who were younger than 40 years, given that a high prevalence of cardiovascular risks, including obesity, hyperlipidemia, hypertension, and type 2 diabetes in this population. In addition, young adults are more likely to have a long sedentary duration (> 6 h per day) and less physical exercise associated with CVD risk in the current study. Given early life prevention of CVD will yield greater health benefits and the high prevalence of CVD risks among young people, our sample, including young adults, guarantees a more comprehensive profile of the association between sleep duration and CVD risk among adults. Being different from other studies, we have collected data on sedentary behavior and sleep quality except for conventional cardiovascular risk factors. We found both sedentary behavior and sleep quality were associated with CVD risk and might be involved in the relationship between sleep duration and CVD risk. Although a few studies adjusted sleep quality in multivariate regressions, this is the first to adjust both sleep quality and sedentary behavior. It helps to rule out the confounding effects of these two variables on the association between sleep duration and CVD risk, therefore get more reliable results.

Several limitations in our study merit consideration. First, the cross-sectional design of this study limited its ability to identify causal associations between sleep duration and 10-year CVD risk. Second, because the cohort was constructed enrolling a subset of motivated participants who would engage in long-term follow-up rather than prioritize representativeness, we recruited participants in seven medical examination centers Beijing-Tianjin-Hebei region, and only people benefit through employment were included. Most of the participants were of high socioeconomic status (77.00% had college or above education). Therefore, the generalizability of our findings to other geographic regions and the total Chinese populations was uncertain. Lastly, sleep duration in this study was self-reported. Given the large scale of our sample, we couldn't use polysomnography to measure sleep duration. Future studies may use cohort data further to validate the association between sleep duration and CVD risk.

In conclusion, we have described the predicted CVD risk profile among a large sample across a broad range of age groups and examined the association between sleep duration and CVD risk. The current findings help identify adults at risk of CVD and highlight the need for interventions to improve their cardiovascular health. Given the high prevalence of CVD in China, the information may be vital to understand the predicted CVD risk and risk factors among general adults to guide preventive strategies.

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CONFLICT OF INTEREST

Neither I nor my partner has a commercial interest, financial interest, and/or other relationship with manufacturers of pharmaceuticals, laboratory supplies, and/or medical devices or with commercial providers of medically related services. The authors alone are responsible for the views expressed in this article and they do not necessarily represent the views, decisions or policies of the institutions with which they are affiliated. No conflict of interest in connection with this manuscript is present. As the corresponding author, I will be responsible for this paper at the pre-publication stages and handle the proofs.

AUTHORS' CONTRIBUTIONS

All authors have contributed substantially to the study. ZHANG Min Ying has designed, supervised and oversaw the study implementation. WANG Yu Xue conducted the investigation, analysis of the data and wrote the manuscript. ZHANG Li, LI Chun Jun, CHEN Shuo, QI Xin, NIU Yu Jie, and ZHANG Mian Zhi have organized and managed the investigation. FAN Ya Qi, HE Jiang Shan, GUO Pei, Hu Jia Lin, LIU Feng, ZHANG Rong, LI Qiang, MA Shi Tao have participated in the investigation and the management of the data. HONG Cheng Lin facilitated the development of the manuscript. All authors read and approved the final manuscript.

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