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Association between sleep duration and metabolic syndrome: a population-based study in China

Ziyi Sun[1], Xi Yang[2]* , Ling Bai[3], Ridong Huang[4], Zuojie Luo[1], Li Li[1], Yingfen Qin[1], Jia Zhou[1], Liheng Meng[1], Yang Peng[5] , Xinghuan Liang[1]*

[1]*Department of Endocrinology, The First Affiliated Hospital of Guangxi Medical University. Guangxi Endocrine Clinical Key Specialty, Nanning, China*
[2]*Department of Geriatric Endocrinology and Metabolism & Guangxi Key Laboratory of Precision Medicine in Cardio-Cerebrovascular Diseases Control and Prevention & Guangxi Clinical Research Centre for Cardio-Cerebrovascular Diseases, The First Affiliated Hospital of Guangxi Medical University, Nanning, China*
[3]*Department of Cardiology, The First Affiliated Hospital of Guangxi Medical University, Nanning, China*
[4]*Department of Bone and Joint Surgery, The First Affiliated Hospital of Guangxi Medical University, Nanning, China*
[5]*Department of Occupational and Environmental Health, School of Public Health, Guangxi Medical University, Nanning, China*
**These authors have contributed equally to this work and share first authorship.*

Abstract

Introduction: The relationship between sleep duration and metabolic syndrome (MetS) remains debatable. In the present study, we analysed the link between total sleep duration (including nighttime sleep and nap duration) and MetS as well as its components among the Chinese population.

Material and methods: This was a cross-sectional study from a prospective population cohort including 8616 participants over 40 years in Guangxi, China, evaluated from April 2011 to January 2012. MetS was diagnosed using modified criteria from the National Cholesterol Education Program's Adult Treatment Panel III. Sleep information was obtained through a standard self-report-based questionnaire. The connection between sleep duration and MetS prevalence as well as its components was evaluated using a logistic regression model.

Results: After adjusting for potential confoundings, the longer daily sleep duration (≥ 10 hours) group was observed to have the higher odds of having MetS than the reference group with ≥ 7 and < 8 hours of sleep [odds ratio (OR): 1.25, 95% confidence interval (CI): 1.03–1.52, p = 0.023], as well as the highest odds of having elevated triglycerides (OR: 1.25, 95% CI: 1.03–1.52) and fasting blood glucose (OR: 1.21, 95% CI: 1.01–1.45). Further analysis demonstrated that sleeping > 9 hours per night was correlated to MetS in females (OR: 1.27, 95% CI: 1.02–1.58), while napping ≥ 90 minutes was correlated to MetS (OR: 1.44, 95% CI: 1.11–1.87) in males.

Conclusion: Both longer nighttime sleep duration and longer naps may be associated with the development of MetS.

Key words: *sleep duration; daily nap; MetS*

Introduction

Metabolic syndrome (MetS) is a clinical disorder that includes central obesity, hypertension, hyperglycaemia, and dyslipidaemia [1]. MetS can lead to cardiovascular problems and all-cause mortality risk, and it has developed as a global public health concern [2]. In recent years, MetS incidence has risen considerably in numerous nations [3], with a global incidence ranging from 20 to 45% [4]. According to epidemiological research, the total prevalence of MetS among the Chinese population was 24.5% in 2016 [5]. Therefore, identifying modifiable factors is crucial to preventing the onset of MetS.

Sleep is an important factor related to human health, and it is closely related to hormone secretion and metabolic balance in the body [6]. Meanwhile, insufficient or excessive sleep has been demonstrated in epidemiological research to have adverse implications for the body, such as obesity [7], diabetes [8], or cardiovascular events [9]. MetS has long been assumed to be caused by lack of exercise, irregular diets, and a sedentary lifestyle [10]. Moreover, the onset of MetS has been related to sleep duration, which has been identified as a contributing factor as modern civilization has progressed. To date, many studies have analysed the connection between sleep duration and MetS. However, the outcomes of prior investigations were inconsistent. Toshiaki et al. reported a U-shaped relationship in Japanese patients, with both short- and long-duration sleepers presenting a higher risk of MetS [11]. Recent data from

Xinghuan Liang, The First Affiliated Hospital of Guangxi Medical University, No.6 Shuang Yong Road, Nanning, Guangxi 530021, China; e-mail: liangxinghuan@gxmu.edu.cn
Yang Peng, School of Public Health, Guangxi Medical University, No.22 Shuang Yong Road, Nanning, Guangxi 530021; China. e-mail:pyu098@126.com

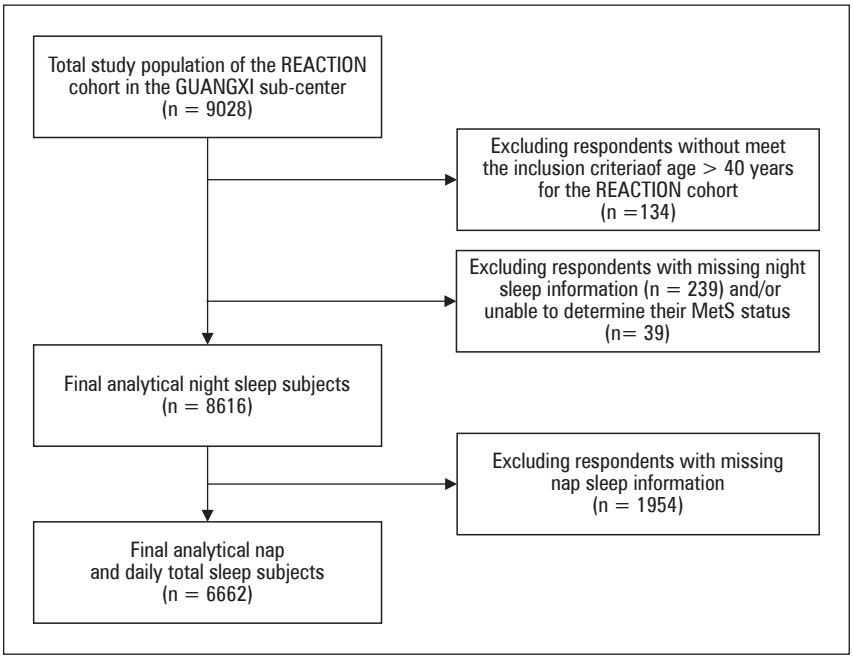


Figure 1. *Flow chart of crowd data analysis from the REACTION study (2011–2012)*

a meta-analysis of 9 prospective cohorts suggests that short sleep duration, rather than extended sleep duration, increases the risk of MetS [12]. On the other hand, another cross-sectional investigation showed no link between sleep duration and MetS in Chinese individuals [13]. These inconsistent results might be related to differences in experimental study designs, race, and sleep duration classification.

Daytime napping is a common behaviour worldwide. In China, around 68.6% of middle-aged and older people nap daily [14]. Adequate napping can aid in energy recovery, memory consolidation [15], and cognitive function [16]. However, obesity [17], type 2 diabetes (T2DM) [18], and cardiovascular issues have also been linked to taking longer naps in several studies [19]. Also, previous studies have reported a correlation between napping and MetS. In the Netherlands, a cross-sectional study indicated that napping for both < 30 and ≥ 30 min was related to an elevated incidence of MetS in 1679 older subjects compared to those who did not nap [20]. Another cross-sectional study conducted in China found that only napping for ≥ 90 min was correlated with significantly higher MetS occurrence among 5129 subjects with an average age of 39 years [21]. Because more middle-aged and elderly people nap during the day in China, understanding the health impacts of napping on MetS is of significant interest.

Most studies on sleep duration and MetS have concentrated on nighttime sleep duration, with relatively few studies looking at nap and total daily sleep duration. An even greater lack of studies is related to the link between the 3 sleep durations and MetS. At the same time, there is controversy regarding the length of sleep duration that affects MetS. Hence, we used data from the REACTION study in Guangxi to evaluate the correlation between total sleep duration (including nighttime sleep duration and naps) and MetS and its components, and to further explore the impacts of gender, age, and BMI status on the sleep-MetS relationship.

Material and methods

Study population

The data for this study were retrieved from the Guangxi division of the Risk Evaluation of cAncers in Chinese diabeTic Individuals: A LONgitudinal (REACTION) study, which is a population-based prospective cohort study with respondents over the age of 40 years. This study was designed to evaluate the association between type 2 diabetes, prediabetes, and cancer risk in the Chinese population [22–24]. A total of 9028 respondents were recruited from April 2011 to January 2012 in 8 communities in Nanning, Guangxi, China. Respondents who did not match the eligibility requirements of age (≥ 40 years, n = 134), lacked nighttime sleep duration (n = 239), or could not determine their MetS status (n = 39) were not included in the current research. Thus, 8616 respondents were included to evaluate nighttime sleep duration and MetS and its components. Respondents lacking nap information (n = 1954) were then excluded, and the remaining population (n = 6662) had their daytime nap time and daily sleep time with MetS and its components examined (Fig. 1). The present study followed the Declaration of Helsinki and was authorized by the Human Research Ethics Committee of the First Affiliated Hospital of Guangxi Medical University. Written informed consent form was signed by all the respondents.

Clinical information and biochemical data

Professional researchers performed personal interviews using a systematic questionnaire. The questionnaire included general information, lifestyle factors, and medical and family histories. Never, ever (stopped smoking or drinking for more than 6 months),

or currently (smoked or drunk regularly in the past 6 months) were used to categorize smoking and drinking behaviours. The intensity, duration, and frequency of physical activity during leisure time were evaluated using a short version of the International Physical Activity Questionnaire (IPAQ) [25]. The anthropometric measures of all respondents were evaluated using a standard methodology by qualified personnel. The blood pressure (BP) of sitting respondents was tested using an automated electronic device (OMRON, Omron, China). The same observer took BP readings 3 times in a row, each 5 minutes apart. The BP value for analysis was calculated as the average of the 3 readings. The waist circumference (WC) was estimated at the umbilical cord in the natural standing position. The body mass index (BMI) (kg/m^2) was computed by multiplying the weight (kg) by the square of the height (m^2). Obesity was defined as a BMI ≥ 28, and overweight was defined as a BMI ≥ 24 and < 28, according to the standards of the Chinese population [26]. Venous blood samples were collected in the early morning when respondents were fasting. Total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), fasting plasma glucose (FPG), and triglyceride (TG) levels were tested using an automated analyser (ARCHITECTc16000System, Abbott Laboratories, IL, United States).

Definition of MetS

MetS was defined following the 2005 National Cholesterol Education Program Modified Adult Standard Treatment Group III (NCEP ATP III) [27] and was diagnosed as a condition in which 3 or more of the following features were present:

— women's and men's WCs of 90 and 80 cm, respectively;
— TG ≥ 1.70 mmol/L or medication therapy for high triglycerides;
— HDL-C levels of < 1.03 and < 1.30 mmol/L for men and women, respectively;
— systolic blood pressure (SBP) ≥ 130 mmHg, diastolic blood pressure (DBP) ≥ 85 mm Hg or medication therapy for high BP;
— FPG ≥ 5.6 mmol/L or medication therapy for high fasting glucose.

Definition criteria of total sleep duration, nighttime sleep duration, and nap duration

Sleep duration was evaluated based on the following questions: When do you generally sleep at night? When do you normally get up in the morning? Do you take naps during the day? How long do you generally slumber — minutes or hours? Waking and falling asleep times were used to compute nighttime sleep duration. Nighttime sleep was separated into 5 categories: < 6 h, ≥ 6 and < 7 h, ≥ 7 and < 8 h, ≥ 8 and < 9 h, and ≥ 9 h. Daytime naps were classified into 3 categories: ≥ 1 and < 45 min, ≥ 45 and < 90 min, and ≥ 90 min. Based on the sum of nighttime sleep and nap duration, the total sleep duration was divided into 5 categories: < 7 h, ≥ 7 and < 8 h, ≥ 8 and < 9 h, ≥ 9 and < 10 h, and ≥ 10 h.

Statistical analyses

The Kolmogorov-Smirnov (K-S) test was applied to determine normality. Continuous variables are presented as means ± standard deviations or medians (interquartile ranges). Frequencies and percentages are used to express categorical variables. To contrast non-MetS and MetS groups on continuous variables, the Wilcoxon rank-sum test was employed, while the χ^2 test was utilized to compare categorical data. The odds ratios (ORs) and 95% confidence intervals (CIs) for different sleep durations and MetS were computed using logistic regression analyses. The reference groups were the ≥ 1 and < 45 min nap group and the ≥ 7 and < 8 h sleep group. We performed 2 types of logistic model analyses: model 1 was unadjusted for confounding factors, model 2 was adjusted for age and gender, ethnicity, education, smoking status, drinking status, work intensity, physical activity and BMI.

We also focused on whether age and BMI affected the connection between sleep duration and MetS. After stratifying the research sample by gender, we analysed the connection between MetS and sleep duration in subgroups of age (40–60 and < 60 years) and obesity degree (normal, overweight, or obese). To make our research more comprehensive, a multivariate logistic regression model was used to evaluate the relationship between sleep duration and MetS components. The SAS software (version 9.4) was used for all statistical analyses, and the significance was determined by a p value < 0.05.

Results

Characteristics of respondents

The characteristics of respondents with and without MetS are compared in Table 1. Among the 8616 respondents (3268 males and 5348 females), 3252 (37.7%) had MetS. The respondents' average age was 56.1 ± 10.7 years, and men (34.0%) showed a lower incidence of MetS than women (40.0%). The mean WC and FPG were 83.0 ± 9.1 cm and 5.9 ± 1.7 mmol/L, respectively. Respondents with MetS had higher WC, FPG, BP, and TG levels and BMI compared with non-MetS respondents (all p < 0.05).

Association between sleep duration and MetS

The ORs (95% CI) for MetS according to different sleep durations are displayed in Figure 2. In the total population, sleeping ≥ 9 hours at night and ≥ 10 hours per day exhibited a higher incidence of MetS compared to the control group, with ORs (95% CI) of 1.32 (1.14–1.52) and 1.41 (1.19–1.67), respectively (Model 1). After controlling for age, gender, ethnicity, education, smoking status, drinking status, work intensity, physical activity, and BMI, this correlation (OR: 1.18,95% CI: 1.00–1.40, p = 0.047; OR: 1.25, 95% CI: 1.03–1.52, p = 0.023) is attenuated (Model 2). In male subjects, respondents in the napping duration ≥ 90 min group and with longer daily sleep duration (≥ 10 hours) were significantly linked with MetS (OR: 1.44, 95% CI: 1.11–1.87, p = 0.007; OR: 1.42, 95% CI: 1.04–1.95, p = 0.028). In female subjects a similar connection was only detected between longer night sleep duration (≥ 9 hours) and MetS (OR: 1.27, 95% CI: 1.02–1.58, p = 0.031). We did not detect a significant correlation between short sleep duration and MetS.

Table 2 shows how the correlation between sleep duration and MetS varied among subgroups stratified by age and BMI. After correcting for multiple confounders, napping time ≥ 90 minutes in male subjects was positively related to MetS in the following subgroups: 40–60 years (OR: 1.53, 95% CI: 1.08–2.15) and overweight (OR: 1.79, 95% CI: 1.26–2.53). Female subjects with ≥ 9 hours of nighttime sleep were significantly more susceptible to MetS in the subgroup aged ≥ 60 years (OR: 1.66, 95% CI: 1.22–2.27). The interaction *p*-values for gender, age, and BMI were significant for MetS (all p < 0.001).

Table 1. *Characteristics of respondents with and without metabolic syndrome (MetS)*

Characteristic	Total (n = 8616)	Non-MetS (n = 5364)	MetS (n = 3252)	p-value
Male (n%)	3268 (37.93)	2156 (40.19)	1112 (34.19)	
Age [years]	56.11 ± 10.65	54.12 ± 10.24	59.40 ± 10.51	< 0.001
BMI [kg/m^2]	24.13 ± 3.31	23.13 ± 3.00	25.76 ± 3.14	< 0.001
Ethnicity				**< 0.001**
Han (n%)	5492 (64.90)	3338 (62.23)	2254 (69.31)	
Zhuang (n%)	2666 (30.94)	1811 (33.76)	855 (26.29)	
Other (n%)	114 (1.32)	77 (1.44)	37 (1.14)	
Missing (n%)	244 (2.83)	133 (2.57)	106 (3.26)	
Education				**< 0.001**
Primary school and below (n%)	1437 (16.68)	658 (12.27)	779 (23.95)	
Junior high school (n%)	2811 (32.63)	1729 (32.23)	1082 (33.27)	
High school and technical Secondary school (n%)	3062 (35.54)	2092 (39.00)	970 (29.83)	
College degree or above (n%)	1268 (14.72)	859 (16.01)	409 (12.58)	
Missing (n%)	38 (0.44)	25 (0.48)	12 (0.37)	
Smoking status				**0.001**
Never (n%)	6597 (76.57)	4024 (75.02)	2573 (79.12)	
Former (n%)	621 (7.21)	387 (7.21)	234 (7.20)	
Current (n%)	1252 (14.53)	859 (16.01)	393 (12.08)	
Missing (n%)	146 (1.69)	94 (1.75)	52 (1.60)	
Alcohol consumption status				**< 0.001**
Never (n%)	5143 (59.69)	3091 (57.62)	2052 (63.10)	
Former (n%)	603 (7.00)	378 (7.05)	225 (6.92)	
Current (n%)	2729 (31.67)	1805 (33.65)	924 (28.41)	
Missing (n%)	141 (1.64)	90 (1.68)	51 (1.57)	
Work intensity				**< 0.001**
No work (n%)	5145 (59.71)	2860 (53.32)	2285 (70.26)	
Low intensity (n%)	2686 (31.17)	1952 (36.39)	734 (22.57)	
Moderate intensity (n%)	566 (6.57)	400 (7.46)	166 (5.10)	
High intensity (n%)	100 (1.16)	64 (1.19)	36 (1.11)	
Missing (n%)	119 (1.38)	84 (1.63)	31 (0.95)	
Physical activity				**< 0.001**
No (n%)	1453 (16.86)	943 (17.58)	510 (15.68)	
Low level (n%)	4579 (53.15)	2709 (50.50)	1870 (57.50)	
Moderate (n%)	1250 (14.51)	804 (14.99)	446 (13.71)	
High level (n%)	1153 (13.38)	789 (14.71)	364 (11.19)	
Missing (n%)	181 (2.10)	119 (2.22)	62 (1.91)	
Changes in Mets components				
WC [cm]	83.04 ± 9.07	79.73 ± 8.13	88.41 ± 7.89	< 0.001
TG [mmol/L]	1.55 ± 1.27	1.16 ± 0.72	2.19 ± 1.65	< 0.001
HDL-c [mmol/L]	1.31 ± 0.41	1.39 ± 0.43	1.18 ± 0.34	< 0.001
SBP [mmHg]	132.03 ± 20.21	125.78 ± 18.52	142.20 ± 18.66	< 0.001
DBP [mmHg]	78.45 ± 11.42	76.02 ± 10.73	82.40 ± 11.41	< 0.001
FPG [mmol/L]	5.90 ± 1.67	5.49 ± 1.24	6.56 ± 2.02	< 0.001

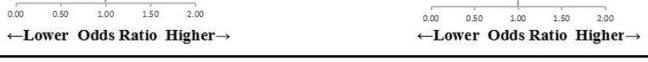
Data are presented as mean ± standard deviation (SD) or number (percentage). p-values were for χ^2 analyses across the groups. BMI — body mass index; TG — triglycerides; HDL-C — high-density lipoprotein cholesterol; SBP — systolic blood pressure; DBP — diastolic blood pressure; FPG — fasting plasma glucose

A

Nighttime sleep duration	Number	Prevalence of MetS	Model 1 OR(95 %CI)	Model 1 *P* value	Model 2 OR(95 %CI)	Model 2 *P* value
Total(n=8616)						
< 6 h	440	161 (36.6)	1.03 (0.84-1.27)	0.775	0.82 (0.65-1.03)	0.091
≥ 6 and < 7 h	1591	575 (36.1)	1.01 (0.89-1.15)	0.867	0.96 (0.84-1.11)	0.601
≥ 7 and < 8 h	3254	1168 (35.9)	1.00	–	1.00	–
≥ 8 and < 9 h	2326	921 (39.6)	1.17 (1.05-1.31)	0.005	1.12 (0.99-1.27)	0.080
≥ 9 h	1005	427 (42.5)	1.32 (1.14-1.52)	<0.001	1.18 (1.00-1.40)	0.047
Male(n=3268)						
< 6 h	191	60 (31.4)	0.94 (0.68-1.30)	0.701	0.68 (0.47-0.99)	0.042
≥ 6 and < 7 h	612	199 (32.5)	0.99 (0.80-1.21)	0.899	0.96 (0.76-1.21)	0.723
≥ 7 and < 8 h	1271	417 (32.8)	1.00	–	1.00	–
≥ 8 and < 9 h	792	288 (36.4)	1.17 (0.97-1.41)	0.098	1.17 (0.95-1.44)	0.146
≥ 9 h	402	148 (36.8)	1.19 (0.94-1.51)	0.139	1.09 (0.83-1.43)	0.542
Female(n=5348)						
< 6 h	249	101 (40.6)	1.12 (0.86-1.47)	0.410	0.90 (0.66-1.22)	0.485
≥ 6 and < 7 h	979	376 (38.4)	1.02 (0.87-1.20)	0.778	0.99 (0.82-1.18)	0.865
≥ 7 and < 8 h	1983	751 (37.9)	1.00	–	1.00	–
≥ 8 and < 9 h	1534	633 (41.3)	1.15 (1.01-1.32)	0.041	1.13 (0.97-1.32)	0.124
≥ 9 h	603	279 (46.3)	1.41 (1.18-1.70)	<0.001	1.27 (1.02-1.58)	0.031

B

Nap sleep duration	Number	Prevalence of MetS	Model 1 OR(95 %CI)	Model 1 *P* value	Model 2 OR(95 %CI)	Model 2 *P* value
Total (n=6662)						
≥ 1 and < 45 min	1702	617 (36.25)	1.00	–	1.00	–
≥ 45 and < 90 min	3259	1200 (36.82)	1.03 (0.91-1.16)	0.693	1.00 (0.87-1.15)	0.993
≥ 90 min	1701	809 (36.18)	1.26 (1.10-1.45)	< 0.001	1.06 (0.91-1.24)	0.461
Male (n=2591)						
≥ 1 and < 45 min	617	191 (31.0)	1.00	–	1.00	–
≥ 45 and < 90 min	1307	431 (33.0)	1.10 (0.89-1.35)	0.377	1.10 (0.87-1.38)	0.431
≥ 90 min	667	272 (40.8)	1.54 (1.22-1.93)	< 0.001	1.44 (1.11-1.87)	0.007
Female (n=4071)						
≥ 1 and < 45 min	1085	426 (39.3)	1.00	–	1.00	–
≥ 45 and < 90 min	1952	769 (39.4)	1.01 (0.86-1.17)	0.943	0.99 (0.84-1.18)	0.950
≥ 90 min	1034	439 (42.5)	1.14 (0.96-1.36)	0.135	0.95 (0.78-1.16)	0.642



C

Daily sleep duration	Number	Prevalence of MetS	Model 1 OR(95 %CI)	Model 1 *P* value	Model 2 OR(95 %CI)	Model 2 *P* value
Total (n=6662)						
< 7 h	506	183 (36.17)	1.03 (0.83-1.27)	0.823	0.96 (0.76-1.23)	0.756
≥ 7 and < 8 h	1292	460 (35.60)	1.00	–	1.00	–
≥ 8 and < 9 h	2236	809 (36.18)	1.03 (0.89-1.18)	0.731	1.06 (0.90-1.25)	0.463
≥ 9 and < 10 h	1626	637 (39.18)	1.17 (1.00-1.36)	0.048	1.07 (0.90-1.28)	0.425
≥ 10 h	1002	439 (43.81)	1.41 (1.19-1.67)	< 0.001	1.25 (1.03-1.52)	0.023
Male (n=2591)						
< 7 h	213	68 (31.9)	0.95 (0.67-1.33)	0.750	0.87 (0.59-1.28)	0.491
≥ 7 and < 8 h	519	172 (33.1)	1.00	–	1.00	–
≥ 8 and < 9 h	889	280 (31.5)	0.93 (0.74-1.17)	0.524	0.98 (0.76-1.27)	0.890
≥ 9 and < 10 h	588	218 (37.1)	1.19 (0.93-1.52)	0.172	1.23 (0.93-1.63)	0.149
≥ 10 h	382	156 (40.8)	1.39 (1.06-1.83)	0.018	1.42 (1.04-1.95)	0.028
Female (n=4071)						
< 7 h	293	115 (39.2)	1.09 (0.83-1.43)	0.549	0.97 (0.71-1.33)	0.864
≥ 7 and < 8 h	773	288 (37.3)	1.00	–	1.00	–
≥ 8 and < 9 h	1347	529 (39.3)	1.09 (0.91-1.31)	0.359	1.12 (0.91-1.38)	0.294
≥ 9 and < 10 h	1038	419 (40.4)	1.14 (0.94-1.38)	0.18	1.01 (0.81-1.26)	0.935
≥ 10 h	620	283 (45.6)	1.41 (1.14-1.75)	0.002	1.20 (0.94-1.55)	0.147

Figure 2. *The odds ratios (ORs) of metabolic syndrome (MetS) based on nighttime sleep duration (***A***), nap duration (***B***), and daily sleep duration (***C***) in the REACTION study (2011–2012). Model 1: crude ratio. Model 2: adjusted for age, gender (as appropriate), ethnicity, education, smoking status, alcohol consumption status, work intensity, physical activity, and body mass index (BMI)*

Relationship between sleep duration and MetS components

Figure 3 presents the results of the multivariate logistic regression analysis between sleep duration and MetS components. For all participants, with elevated TG (OR: 1.25, 95% CI: 1.03–1.52) and FPG (OR: 1.21, 95% CI: 1.01–1.45) being linked to ≥ 10 hours of sleep per day compared to the reference group. Of elevated TG, ≥ 9 hours of sleep per night also presented similar results (OR: 1.23, 95% CI: 1.05–1.45). For males, re-

Table 2. *Subgroup analysis of sleep duration and metabolic syndrome (MetS)*

Variables	Age		BMI		
	40–60 y	≥ 60 y	Normal	Overweight	Obesity
Male					
Nighttime sleep duration (n = 8616)					
Number	2137	1129	1455	1352	388
< 6 h	0.51 (0.31–0.85)	1.08 (0.60–1.92)	0.79 (0.38–1.66)	0.74 (0.44–1.24)	0.70 (0.33–1.48)
≥ 6 and < 7 h	0.85 (0.64–1.14)	1.24 (0.83–1.85)	1.08 (0.71–1.64)	0.82 (0.60–1.12)	1.52 (0.80–2.89)
≥ 7 and < 8 h	Ref	Ref	Ref	Ref	Ref
≥ 8 and < 9 h	1.07 (0.82–1.41)	1.42 (1.02–1.97)	1.40 (0.98–2.02)	1.01 (0.77–1.34)	1.41 (0.75–2.67)
≥ 9 h	1.07 (0.74–1.53)	1.29 (0.86–1.94)	1.14 (0.72–1.82)	1.22 (0.85–1.76)	0.77 (0.37–1.60)
Nap sleep duration (n = 6662)					
Number	1653	936	1123	1094	310
≥ 1 and < 45 min	Ref	Ref	Ref	Ref	Ref
≥ 45 and < 90 min	1.26 (0.95–1.67)	0.88 (0.59–1.31)	0.83 (0.55–1.25)	1.32 (0.97–1.79)	0.90 (0.49–1.67)
≥ 90 min	1.53 (1.08–2.15)	1.32 (0.86–2.02)	1.22 (0.77–1.93)	1.79 (1.26–2.53)	0.97 (0.48–1.97)
Daily sleep duration (n = 6662)					
Number	1653	936	1123	1094	310
< 7 h	0.89 (0.55–1.43)	0.79 (0.41–1.55)	0.73 (0.30–1.81)	0.89 (0.53–1.50)	0.73 (0.30–1.81)
≥ 7 and < 8 h	Ref	Ref	Ref	Ref	Ref
≥ 8 and < 9 h	1.10 (0.80–1.53)	0.76 (0.49–1.19)	0.75 (0.38–1.47)	1.21 (0.85–1.71)	0.75 (0.38–1.47)
≥ 9 and < 10 h	1.47 (1.02–2.13)	0.96 (0.61–1.50)	0.78 (0.36–1.66)	1.46 (1.00–2.12)	0.78 (0.36–1.66)
≥ 10 h	1.44 (0.94–2.21)	1.35 (0.83–2.19)	0.78 (0.32–1.90)	1.67 (1.09–2.58)	0.78 (0.32–1.90)
Female					
Nighttime sleep duration (n = 8616)					
Number	3323	2024	2854	1851	557
< 6 h	0.95 (0.61–1.47)	0.88 (0.58–1.34)	0.69 (0.43–1.12)	0.95 (0.60–1.52)	0.99 (0.43–2.28)
≥ 6 and < 7 h	1.01 (0.80–1.27)	0.99 (0.75–1.32)	1.10 (0.84–1.43)	0.93 (0.71–1.22)	0.79 (0.48–1.32)
≥ 7 and < 8 h	Ref	Ref	Ref	Ref	Ref
≥ 8 and < 9 h	1.11 (0.91–1.37)	1.14 (0.90–1.45)	1.17 (0.94–1.47)	1.11 (0.87–1.42)	1.01 (0.63–1.63)
≥ 9 h	1.04 (0.77–1.41)	1.66 (1.22–2.27)	1.36 (1.01–1.82)	1.09 (0.77–1.55)	1.37 (0.68–2.75)
Nap sleep duration (n = 6662)					
Number	2492	1578	2172	1403	425
≥ 1 and < 45 min	Ref	Ref	Ref	Ref	Ref
≥ 45 and < 90 min	1.05 (0.83–1.32)	0.93 (0.72–1.21)	0.95 (0.74–1.21)	1.00 (0.76–1.31)	1.08 (0.62–1.87)
≥ 90 min	0.89 (0.68–1.17)	1.04 (0.77–1.40)	1.01 (0.76–1.33)	0.87 (0.63–1.18)	1.02 (0.57–1.83)
Daily sleep duration (n = 6662)					
Number	2492	1578	2172	1403	425
< 7 h	0.90 (0.60–1.38)	1.14 (0.71–1.84)	1.06 (0.67–1.68)	0.90 (0.55–1.46)	1.03 (0.42–2.49)
≥ 7 and < 8 h	Ref	Ref	Ref	Ref	Ref
≥ 8 and < 9 h	1.13 (0.86–1.47)	1.04 (0.76–1.44)	1.32 (0.97–1.80)	0.95 (0.69–1.29)	1.32 (0.70–2.51)
≥ 9 and < 10 h	1.05 (0.79–1.41)	0.99 (0.71–1.37)	1.02 (0.74–1.42)	1.04 (0.74–1.45)	1.21 (0.63–2.33)
≥ 10 h	0.98 (0.70–1.39)	1.56 (1.07–2.26)	1.27 (0.88–1.83)	1.10 (0.75–1.63)	1.37 (0.66–2.85)

Adjusted for age (as appropriate), BMI (as appropriate), ethnicity, education, smoking status, alcohol consumption status, work intensity, physical activity.
BMI — body mass index

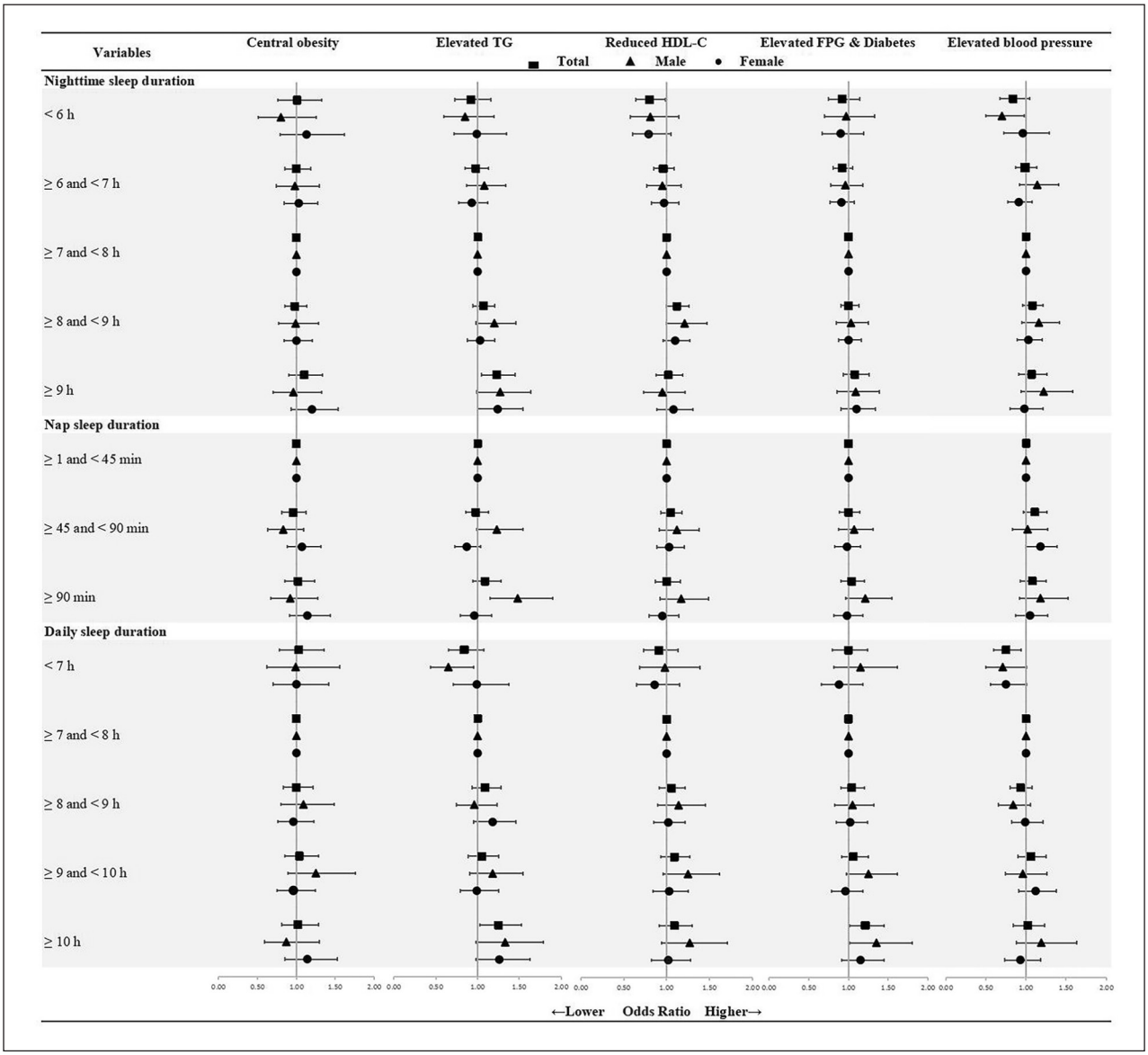


Figure 3. *Adjusted odds ratios (ORs) for metabolic syndrome (MetS) components based on nighttime sleep duration, nap duration, and daily sleep duration in the REACTION study (2011–2012) adjusted for age, gender (as appropriate), body mass index (BMI), ethnicity, education, smoking status, alcohol consumption status, work status, and physical activity*

spondents who napped for ≥ 90 minutes had a higher risk of elevated TG (OR: 1.48 95% CI: 1.15–1.90). For females, although the statistically relevant connection between longer nighttime sleep duration and elevated TG was weaker, we still noticed a trend (OR: 1.24 95% CI: 1.00–1.54).

Sensitivity analysis

The association between nighttime sleep duration and MetS was investigated in Supplementary File — Table S1 using the data excluding missing nap information. The sensitivity analysis was similar to the primary analysis. Compared with women who slept 7–8 hours at night, those who slept more than 9 hours at night exhibited a higher chance of MetS in the non-adjusted model. The association in the sensitivity analysis was slightly attenuated compared to that in the primary analysis in the adjusted model.

Discussion

In the current cross-sectional study, we presented epidemiological evidence that excessive night sleep duration and total sleep duration might contribute to the onset of MetS among the Chinese population. Further subgroup analyses revealed that sleep duration ≥ 9 hours per night was linked to MetS development in older Chinese females. Daytime naps of ≥ 90 minutes were linked to a considerable increase in MetS prevalence in middle-aged overweight Chinese males. According to

gender variations in the night sleep and nap connections with MetS, men might be more vulnerable to napping, whereas women may be more influenced by nighttime sleep. Our current findings indicate that longer nighttime sleep and total daily sleep duration might be detrimental to MetS components, including TG and FPG.

Previous studies have only shown that a short or long nighttime sleep duration was linked to MetS, or that sleep duration presented a U-shaped pattern with MetS risk [28–30]. Hence, the findings regarding the link between nighttime sleep duration and MetS are controversial. Longer nightly sleep (≥ 9 h) was related to MetS in women over 60 years old, but not in men, according to our survey. The exact cause for these gender differences remains unclear. Hormonal changes and their effects on sleep could be one explanation for the gender-specific differences in this connection [31]. Previously, fluctuations in reproductive hormone levels in women during menopause have been associated with decreased oestrogen levels and sleep disturbances [32, 33]. Studies have also indicated that perimenopausal women tend to have hot flashes during nighttime sleep, which are characterized by intense heat, sweating, and dilation of skin blood vessels [34]. Moreover, post-hot flashes in women were negatively correlated with sleep efficiency and increased nocturnal awakenings, which might lead to decreased sleep quality and increased sleep demand, finally resulting in increased nighttime sleep [35]. Also, a meta-analysis mentioned that women who slept longer had an elevated degree of C-reactive protein and interleukin 6 (IL-6) inflammatory markers than men [36]. The levels of inflammatory markers also affect BP, WC, and insulin sensitivity, which might contribute to MetS [37].

Napping has long been considered a beneficial lifestyle habit. However, recent studies have shown that prolonged napping can be detrimental to health. According to a previous meta-analysis, prolonged napping was related to the occurrence of cardiovascular events and all-cause mortality [38]. Additionally, a cohort study found that longer napping was a possible risk factor for the onset of MetS and negatively affected MetS recovery [30]. Although we did not identify a link between napping and MetS in the general population, in the subgroup analyses by gender and BMI, we found that napping for ≥ 90 min was linked to an elevated risk of MetS in overweight men between the ages of 40 and 60 years. The mechanism behind this connection remains unknown. In previous studies, increased sympathetic activity was detected after waking from a daytime nap. In particular, prolonged napping might lead to sympathetic and vagal equilibrium breakdowns, thereby activating the renin-angiotensin system that regulates insulin production and glycaemic regulation, finally resulting in abnormal glucose metabolism [39]. Meanwhile, prolonged daytime napping might cause circadian rhythm disturbances, leading to increased nighttime cortisol concentrations and predisposition to insulin resistance and other metabolic abnormalities [40]. Furthermore, prolonged napping might be caused by lack of sleep or nocturnal sleep disorders. Thus, the increased risk of diabetes or metabolic illness on these individuals might be related to chronic nocturnal sleep deprivation or sleep disturbances rather than prolonged daytime napping [41].

Few studies have explored the link between MetS and the total sleep duration (nighttime sleep and napping throughout the day). In Korea, a prospective study reported an OR (95% CI) of 1.41 (1.06–1.08) for the occurrence of MetS when comparing a total sleep time of ≥ 6 and < 8 h with < 6 h [42], but it did not analyse gender interactions. Moreover, Wu et al. [13] reported a link between daily sleep duration and MetS in a Chinese population and showed that female respondents with sleep duration ≥ 8 h were more prone to MetS. However, this study did not detect the difference between sleep duration and MetS in men. Regarding the relative connection between daily sleep duration and MetS, we showed that among overweight men and women aged ≥ 60 years, excessive daily sleep duration (≥ 10 hours/day) was related to MetS. Excessive total daily sleep duration leading to MetS might be due to deprivation of physical activity and excessive fat accumulation in prolonged sleepers. Additionally, lipocalin is an important adipocytokine that protects against hypertension, inflammation, and atherosclerotic vascular disease. Lipocalin expression decreases in people with visceral fat build-up, which might be one of the reasons why prolonged sleep leads to MetS [43]. Second, in terms of MetS composition, we showed that longer daily sleep duration was linked to higher TG and FPG levels, consistent with previous observations.

Our present study has some limitations. First, we described a relationship between sleep duration and metabolic risk factors, but the underlying causes could not be inferred. Second, although we adjusted for different possible risk variables, residual confounding can be caused by unobserved or inaccurately calibrated variables, including sleep breathing disorders and other sleep disturbances. Finally, we relied on self-reported personal information such as sleep time, which might contribute to bias in the experimental findings. The lack of objective measures of sleep to go with the objective measures of MetS was a major limitation. On the other hand, our study has the advantage of adjusting for more covariates in a large sample of individuals and adding the effects of longer naptime and MetS in men.

Conclusion

This study reveals that excessive daily sleep duration (both nap and night sleep duration) seems to be a detrimental factor for MetS and its components, with overweight middle-aged men being primarily affected by nap duration and older women being primarily affected by night sleep duration. To maintain a proper sleep schedule and limit the development of MetS, it is desirable to enhance sleep-related health education in the prevention and control of MetS.

Data availability statement

The datasets generated and/or analysed during the current study are not publicly available due to their containing information that could compromise research participant privacy, but they are available from the corresponding author on reasonable request.

Ethics statement:

This study was approved by the Human Research Ethics Committee of the First Affiliated Hospital of Guangxi Medical University, and all procedures were performed in accordance with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Written informed consent was obtained from all participants or their proxies.

Author contributions

Z.Y.S. and L.B. conceived and analysed the data and drafted the initial manuscript; Z.J.L., Y.F.Q., X.H.L., and L.H.M. designed the study and assisted with data collection, R.D.H. and L.L. were responsible for data image processing, Y.P. and J.Z. analysed the data and revised the manuscript. X.Y. reviewed the manuscript. All authors approved the final manuscript as submitted and agreed to take responsibility for all aspects of the work.

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Conflict of interest

The authors have no conflicts of interest to disclose.

Supplementary material

There are 3 Supplementary Tables.

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