Endocrine (2019) 66:240–248
https://doi.org/10.1007/s12020-019-02064-y

ORIGINAL ARTICLE

Associations of sleep durations and sleep-related parameters with metabolic syndrome among older Chinese adults

Yu-Xi Qian[1] · Jing-Hong Liu[1] · Qing-Hua Ma[2] · Hong-Peng Sun[1] · Yong Xu[1] · Chen-Wei Pan[1]

Received: 14 November 2018 / Accepted: 20 August 2019 / Published online: 31 August 2019

Abstract

Purpose There is a lack of data on the role of sleep in the development of metabolic syndrome (MetS) in older adults. We aimed to examine the associations of sleep durations at night and other sleep-related parameters with the presence of MetS in older Chinese adults.

Methods Data of 4579 individuals aged 60 years or older from the Weitang Geriatric Disease Study were analyzed. MetS was diagnosed based on the Adult Treatment Panel III (ATP III) criteria. Information regarding sleep durations and other sleep-related parameters was collected by questionnaires.

Results Compared with those with daytime napping, individuals without daytime napping were at an increased risk of MetS (odds ratio [OR] = 1.23; 95% confidence interval [CI] = 1.03–1.47). Each hour increase in daytime napping increased the risk of MetS by 33% (OR = 1.33; 95% CI = 1.15–1.52). After adjusting for the effect of age and gender, a J-shaped association between sleep durations at night and the presence of MetS was observed. The risk of MetS was lowest among those who slept 7–8 h at night. Gender-stratified analysis indicated that the J-shaped relationship between sleep durations at night and MetS remained significant in men but not in women.

Conclusions In older Chinese adults, sleep durations at night might have a dual effect on the risk of MetS and this effect was particularly pronounced in men. The results indicated that circadian rhythm might play an important role in the development of MetS in older populations.

Keywords Metabolic syndrome · Sleep duration · Older adults · Epidemiology

Introduction

Metabolic syndrome (MetS), a global public health concern [1], is linked with a wide range of chronic conditions including type 2 diabetes mellitus, cardiovascular diseases, cognitive impairment, and increased risks of mortality [2–4]. Identifying preventable risk factors for MetS is urgent for lowering the disease burdens from public health perspectives. While many epidemiological studies among the elderly found a U-shaped association between sleep durations and some specific components of MetS such as hypertension [5], obesity [6], diabetes [7], hypercholesterolemia [8], the exact quantity of sleep durations associated with MetS remains unclear. Previous studies have suggested that sleep might be related to the risk of MetS but most studies focused on young generations or mixed-age population, which mostly exhibited a U-shaped association of sleep durations with MetS [9–16]. Considering the age-specific variations in circadian rhythms between the old and young, these findings from younger generations could not be directly extrapolated to older adults [17]. To the best of our knowledge, only one study on Swedish adults aged 65 years or older found that longer sleep durations were associated with a higher prevalence of MetS but the findings from a single study are far from conclusive [18]. Ethnic differences in sleep patterns may exist as more family burdens and financial insecurity during retirement in Chinese than the Whites may result in a higher level of stress hormone cortisol in older Chinese and ultimately associate with more common short sleep durations in Chinese [19–21].

These author contributed equally: Yu-Xi Qian, Jing-Hong Liu

✉ Chen-Wei Pan
pcwonly@gmail.com

1 School of Public Health, Medical College of Soochow University, Suzhou, China

2 The 3rd People's Hospital of Xiangcheng District, Suzhou, China

As world's most populous country, more than half of the Chinese older populations were affected by MetS and China might have the greatest burden of MetS [22–24]. However, there was limited evidence to valid the association of sleep with MetS among older Chinese. In this study, we examined the associations between sleep-related variables and the presence of MetS among older Chinese adults. Considering the possible dual effect of sleep durations on MetS, we explored whether a U-shaped or J-shaped association between sleep durations and MetS existed in older Chinese. In addition, we also investigated the interaction effects between sleep durations and other demographic or socioeconomic variables to better understand the sleep–MetS relationship. The findings would provide novel insights into the role of circadian rhythm in the development of MetS in Chinese older populations.

Methods

Study population

The Weitang Geriatric Diseases Study is a community-based cross-sectional study on Chinese adults aged 60 years or older living in the Weitang town of Suzhou located in the eastern part of China. The study protocol and some significant findings have been described elsewhere [25–27]. In brief, 6030 individuals aged 60 years or older were invited to participate in the study based on the official records. A participant was considered "ineligible" to participate if he or she had moved from the residing address, had not been living there for more than 6 months, or was deceased. We totally identified 5613 eligible individuals, of whom, 4611 eventually attended the clinical examinations between August 2014 and February 2015. Complete data on interviewer-administered questionnaires and blood samples were obtained for 4579 individuals.

The study was conducted following the tenets of the Helsinki Declaration and was approved by the Institutional Review Board of Soochow University.

Definition of MetS

According to the Adult Treatment Panel III (ATP III) criteria, MetS components consist of five conditions: (a) body mass index (BMI) of 25 kg/m^2 or more; (b) blood pressure (BP) of 130/85 mmHg or higher or on drug treatment for hypertension; (c) blood triglycerides of 150 mg/dL (1.7 mmol/L) or greater; (d) blood high-density lipoprotein (HDL) cholesterol of lower than 40 mg/dL in men and 50 mg/dL in women; (e) fasting plasma glucose of 7.0 mmol/L or above or with a history of diabetes mellitus [28]. An individual was considered to have MetS if he or she was affected by at least three of the above conditions.

Clinical examinations

Body height was measured without shoes using a wall-mounted tape and body weight was measured with light clothing using a digital scale. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). BP was measured for three times or more in a 5-min interval, using an automatic digital BP monitor. The data of fasting glucose, HDL cholesterol, and serum triglycerides were obtained from blood sample analysis.

Measurement of sleep-related parameters

Information regarding night-sleep-duration of the participants was collected by the questions on the usual sleep and wake time in a typical day. To assess the dose–response relationships between sleep durations at night and MetS, sleep durations at night were classified into six groups including "less than 7 h (h)", "7–7.99 h", "8–8.99 h", "9–9.99 h", "10–10.99 h", and "11 h or more". Daytime napping was inquired by the following questions: "Do you have a habit of taking naps? If yes, how long do you sleep?" Participants self-assessed the sleep quality with three severity categories including "good", "intermediate", and "poor".

Questionnaires

Information regarding participants' sociodemographic characteristics (i.e., age, gender, educational attainment, and monthly income) and lifestyle habits (i.e., cigarette smoking, alcohol consumption, tea consumption, and vegetarianism) were collected using predesigned questionnaires. Educational attainment was classified into four categories: no formal education, primary education, secondary education, and university education or higher. Monthly income was categorized as three groups (1000 Yuan or less, 1001–3000 Yuan, and more than 3000 Yuan). Cigarette smoking was categorized into "smokers" or "nonsmokers" while alcohol and tea consumption were divided into "drinkers" and "nondrinkers". Vegetarianism was classified as "nonvegetarian" and "vegetarian".

Statistical analysis

Descriptive statistics were presented as means and standard deviations for continuous variables and percentages for categorical variables. The differences in characteristics such as demographic and behavioral factors by MetS status (present or absent) were compared employing the

Student's t test and chi-square test for continuous and categorical variables, respectively. Multiple logistic regression models were fitted to examine the associations between sleep-related parameters and the presence of MetS. Sleep durations at night were treated as an exposure variable and the presence of MetS was treated as the outcome measure. The square of sleep duration at night was also analyzed to test for the potential U-shaped or J-shaped relationship between sleep durations at night and MetS considering that sleep durations usually have a dual effect on health outcomes. Accordingly, sleep durations at night were treated as both a continuous and categorical variable in the logistic regression models. The first model adjusted for the effect of age and gender and the second additionally adjusted for other potential confounders such as educational attainment, monthly income, and lifestyle habits (e.g., smoking, vegetarianism, alcohol consumption, and tea consumption). We also assessed the dose–response relationships between sleep durations at night and the presence of MetS using trend analysis. Effect estimates including odds ratios (ORs) and their corresponding 95% confidence intervals (CIs) were obtained from the above multiple logistic regression models. Interaction effects were investigated between sleep durations and other five variables (age, gender, education, monthly income, and if the participants were living alone) and stratified-analyses were performed if the interaction effects were statistically significant.

All statistical analysis were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA) and statistical significance was set at 0.05.

Results

Table 1 shows the characteristics of the study participants with and without MetS. Of the 4579 participants, 919 (20.1%) were affected by MetS as defined by the ATP III criteria. The mean age of the study participants was 67.6 (6.3) years. The average systolic blood pressure (SBP) and diastolic blood pressure (DBP) were 144.3 (19.7) and 85.7 (11.2) mmHg, respectively. Participants with MetS were more likely to be women and had a higher SBP, DBP, and BMI compared with those without (all $P < 0.05$).

Table 1 Characteristics of study participants by metabolic syndrome

Characteristic	All persons (n = 4579)	No metabolic syndrome (n = 3660)	Metabolic syndrome (n = 919)	p
Sex (women), %	51.96	48.40	66.12	<0.001
Age, mean (SD), years	67.64 (6.33)	67.81 (6.41)	66.98 (5.96)	0.001
No formal education, %	47.72	47.17	49.89	0.46
Living with spouse, %	82.28	81.83	84.10	0.11
Monthly income				0.64
≤1000 CNY	57.62	57.74	57.14	
1001–3000 CNY	35.46	35.20	36.48	
>3000 CNY	6.92	7.06	6.37	
Former or current smoking, %	34.32	36.51	25.60	<0.001
Alcohol consumption, %	22.59	24.49	15.03	<0.001
Tea consumption, %	34.32	35.58	29.30	<0.001
Vegetarian	1.62	1.39	2.51	0.02
Without physical activities, %	56.15	56.62	54.31	0.21
Working	34.40	36.00	28.00	<0.001
Systolic BP mean(SD), mmHg	144.32 (19.66)	142.67 (19.76)	150.87 (17.84)	<0.001
Diastolic BP mean(SD), mmHg	85.73 (11.21)	84.96 (11.30)	88.79 (10.27)	<0.001
BMI, mean (SD), kg/m^2	23.28 (2.63)	22.79 (2.34)	25.23 (2.82)	<0.001
Hypertension, %	53.81	49.00	72.98	<0.001
Diabetes mellitus, %	11.19	5.80	32.68	<0.001
High BP, %	85.86	82.75	98.25	<0.001
Low HDL, %	22.96	9.81	75.38	<0.001
High triglycerides, %	22.07	9.05	73.97	<0.001
High BMI, %	19.30	11.02	52.29	<0.001

BMI body mass index, *BP* blood pressure, *HDL* high-density lipoprotein, *SD* standard deviation,
CNY Chinese Yuan

Table 2 Association of sleep-related variables with metabolic syndrome

Characteristic	Age, sex-adjusted model		Multivariable-adjusted model*	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Sleep duration per night (h)	1.06 (1.00–1.12)	0.04	1.07 (1.01–1.14)	0.02
Sleep duration per night square (h^2)	1.003 (1.0001–1.01)	0.04	1.004 (1.001–1.007)	0.02
Sleep quality				
Poor	1.00		1.00	
Intermediate	1.08 (0.80–1.46)	0.60	1.07 (0.80–1.45)	0.65
Good	0.95 (0.74–1.21)	0.67	0.95 (0.74–1.22)	0.67
Daytime napping				
Absent	1.00		1.00	
Present	1.23 (1.03–1.47)	0.02	1.20 (1.01–1.44)	0.04
Daytime napping duration (h)	1.33 (1.15–1.52)	<0.001	1.31 (1.14–1.51)	<0.001
Bedtime (24 h)				
≤22	1.00		1.00	
>22	1.39 (1.00–1.92)	0.05	1.32 (0.95–1.83)	0.10
Wake-up time (24 h)				
≤6	1.00		1.00	
>6	1.43 (1.11–1.84)	0.005	1.39 (1.08–1.79)	0.01

OR odds ratio, *CI* confidence interval

[a]Adjusted for age, sex, smoking, alcohol consumption, tea consumption, vegetarianism, monthly income, education level

The associations between sleep-related variables and MetS are displayed in Table 2. Compared with those with daytime napping, individuals without daytime napping were at an increased risk of MetS (OR = 1.23; 95% CI = 1.03–1.47), and each hour increase in daytime napping increased the risk of MetS by 33% (OR = 1.33; 95% CI = 1.15–1.52). In addition, older adults whose bedtime were later than 10 p.m. (OR = 1.39; 95% CI = 1.00–1.92) and whose wake-up time were later than 6 a.m. (OR = 1.43; 95% CI = 1.11–1.84) were more likely to be affected by MetS. After adjusting for potential confounders such as cigarette smoking, alcohol consumption, tea consumption, vegetarianism, monthly income, and educational attainment, the associations of daytime napping habit, daytime napping durations and wake-up time with MetS were remain significant while the association of bedtime with MetS was no longer significant. In both models, no significant differences in self-reported sleep quality between adults with and without MetS were observed. The OR of per hour increase in sleep durations at night for the risk of MetS was 1.06 (95% CI = 1.00–1.12) in the age-gender-adjusted model and 1.07 (95% CI = 1.01–1.14) in the multivariate-adjusted model. The square of sleep duration was also associated with MetS in both models, indicating that there might be a curvilinear relationship between sleep durations at night and the presence of MetS in older adults.

We further performed a dose-response analysis to elucidate the possible curvilinear relationship of sleep durations at night with the risk of MetS and results are shown in Table 3 and Fig. 1. After adjusting for the effect of age and gender, there was a J-shaped association between sleep durations at night and the presence of MetS (Fig. 1). The risk of MetS was lowest among those who slept for 7–8 h at night. Additional adjustment for potential confounders did not alter the effect estimates significantly in the multiple logistic regression models.

We found that gender might be a possible effect modifier on the sleep–MetS relationship (*P* for interaction = 0.035). We further performed a gender-stratified analysis and results are shown in Table 4. We observed that the patterns between sleep durations at night and the presence of MetS were different in men and women. The J-shaped relationship between sleep durations at night and MetS remained significant in all models in men but not in women (Fig. 2). In women, a linear rather than a J-shaped relationship was observed (Fig. 3).

Discussion

In the present study, we observed a J-shaped relationship between sleep duration at night and MetS among older Chinese adults. Furthermore, this pattern seemed to be gender-specific. Abnormal sleep (<7 h and ≥8 h) tended to increase the risk of MetS in men (<7 h and 8–10.99 h) rather than in women. In women, excessive sleep (≥9 h) increased

Table 3 Associations of sleep duration with metabolic syndrome

	At risk *n* (cases)	Age, sex-adjusted model		Multivariable-adjusted model*	
		OR (95% CI)	*p*	OR (95% CI)	*p*
Sleep duration per night (h)					
<7	250 (55)	1.63 (1.12–2.37)	0.010	1.59 (1.10–2.33)	0.015
7–7.99	636 (101)	1.00		1.00	
8–8.99	1495 (299)	1.38 (1.07–1.77)	0.013	1.42 (1.10–1.82)	0.007
9–9.99	1184 (253)	1.49 (1.15–1.93)	0.002	1.54 (1.19–2.01)	0.001
10–10.99	593 (126)	1.59 (1.18–2.15)	0.002	1.66 (1.22–2.24)	0.001
≥11	421 (85)	1.62 (1.15–2.27)	0.005	1.74 (1.23–2.45)	0.002

OR odds ratio, *CI* confidence interval

*Adjusted for age, sex, smoking, alcohol consumption, tea consumption, vegetarianism, monthly income, education level

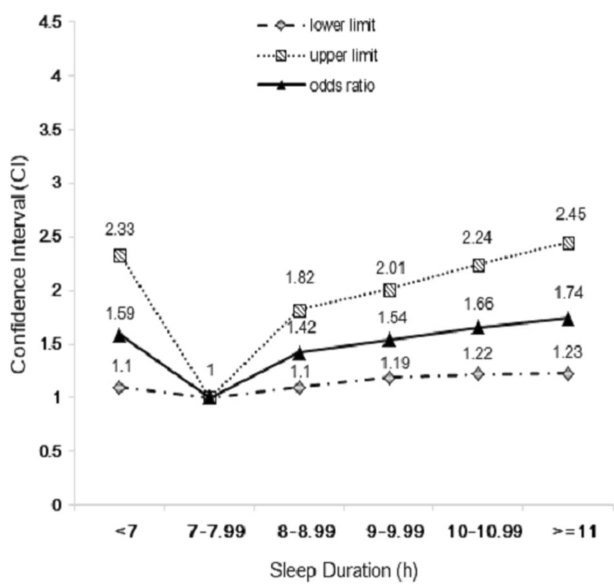

Fig. 1 Association between sleep durations at night and metabolic syndrome (MetS) in all participants

the risk of MetS. These results added the accumulating evidence that the quantity of sleep may be implicated diversely in the occurrence of MetS in men and women.

There has been a growing body of studies suggesting a relevant role of sleep durations in MetS [16, 29]. However, most published studies assessing the association of sleep durations with MetS have been conducted in the middle-aged or mixed-aged populations [9, 14, 30] and limited literatures available in the elderly demonstrated contradictory findings with studies of other age groups [18]. In this regard, comparing with those with a recommended sleep durations of 7–8 h [16, 31], a study in Swedish adults aged 65 years or older found that only long sleep at night (h > 9) was associated with 1.26-fold of MetS [18], which was consistent with the findings in our study. Besides, we also found that participants with short sleep had a 1.59-fold increased risk of MetS. The lack of relationship between short sleep and MetS reported in Swedish may be explained by the discrepancy of sleep durations between the Whites and Chinese [21]. In addition, methodological disparities such as the differences in the sampling frames and the confounding factors adjusted for in the multivariate analyses should be taken into considerations when interpreting the results. While prior studies indicated the association between sleep durations and components of MetS in Chinese [32, 33], limited evidence supported a dual effect of sleep durations on MetS among the elderly [9]. The Harbin Chronic Disease Study found a U-shaped association between sleep durations and MetS among Chinese aged 30–65 years with a lowest risk of sleep durations between 7 and 8 h [9]. We got a similar curvilinear relationship to this study, regardless of variations in age ranges. However, we could not confirm the clinical significance of short sleep on MetS in the elderly on the basis of insufficient data.

Our study indicated that the pattern on the association between sleep durations at night and MetS might vary by gender. The biologic mechanisms underlying the different patterns remain unclear and we provided some possible explanations. First, excessive sleep may compress the waking time of physical activities [32]. Lack of adequate activities can influence the overall well-being of the old people, attributing to obesity, hypertension, and diabetes mellitus, all of which can trigger MetS for women and men [34, 35]. Second, we found that men suffering from somnipathy had a higher prevalence of MetS than women. One possible explanation was that, for those who lack sleep, the decrease of testosterone reduced sympathetic neural response, which existed only in men [36]. This distinction of sympathetic baroreflex function may lead to the variation of related curves [37]. In addition, chronically sleep deprivation would make individuals face more negative events. Men were more likely to be affected by stress and

Table 4 Associations of sleep duration with metabolic syndrome by gender

	At risk *n* (cases)	Model 1[a]		Model 2[b]	
		OR (95% CI)	*p*	OR (95% CI)	*p*
Sleep duration per night (h)					
Men					
<7	153 (34)	2.42 (1.43–4.10)	0.001	2.49 (1.46–4.25)	0.001
7–7.99	317 (33)	1.00		1.00	
8–8.99	761 (170)	1.50 (0.99–2.28)	0.054	1.60 (1.05–2.44)	0.030
9–9.99	530 (78)	1.59 (1.03–2.46)	0.037	1.74 (1.11–2.71)	0.015
10–10.99	258 (37)	1.73 (1.04–2.88)	0.036	1.98 (1.17–3.36)	0.011
≥11	181 (19)	1.34 (0.72–2.47)	0.382	1.65 (0.87–3.11)	0.124
Women					
<7	97 (21)	1.02 (0.58–1.77)	0.953	0.94 (0.54–1.65)	0.836
7–7.99	319 (68)	1.00		1.00	
8–8.99	734 (189)	1.31 (0.95–1.80)	0.096	1.32 (0.96–1.81)	0.091
9–9.99	654 (175)	1.44 (1.04–1.98)	0.028	1.47 (1.06–2.03)	0.020
10–10.99	335 (89)	1.52 (1.05–2.20)	0.028	1.54 (1.06–2.24)	0.028
≥11	240 (66)	1.72 (1.14–2.61)	0.010	1.77 (1.17–2.70)	0.007

OR odds ratio, *CI* confidence interval

[a]Adjusted for age

[b]Adjusted for age, sex, smoking, alcohol consumption, vegetarianism, tea consumption, monthly income, education level

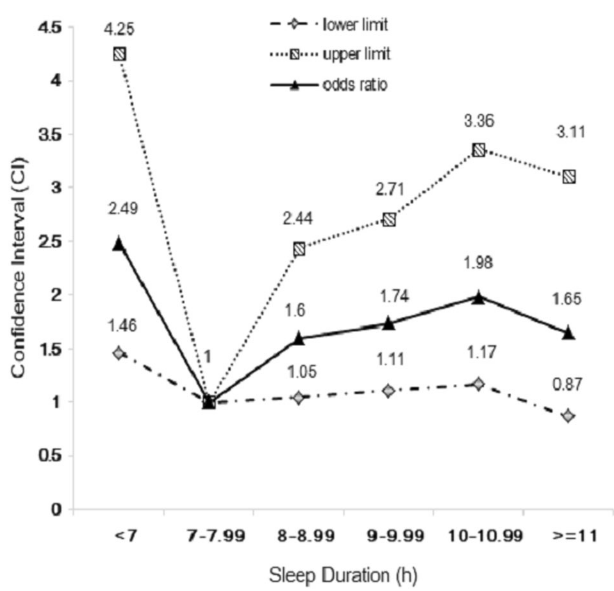

Fig. 2 Association between sleep durations at night and metabolic syndrome (MetS) in men

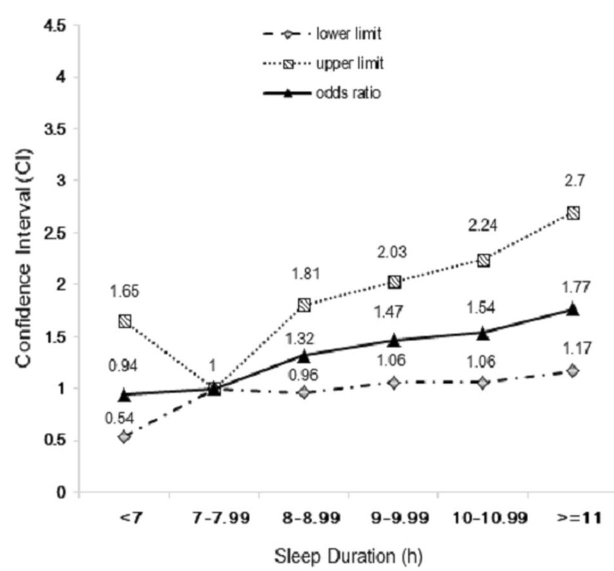

Fig. 3 Association between sleep durations at night and metabolic syndrome (MetS) in women

chronically elevated cortisol levels, which showed up in metabolic changes such as increased appetite, elevated plasma glucose, and extreme fatigue and eventually predispose the high prevalence of MetS [9, 38].

Our study might have some implications regarding the prevention of MetS among the aged population. Considering that the number of people aged 60 or older will reach 2 billion by the year 2050 based on the projection estimates from the World Health Organization [39], the disease burden of MetS in China should not be neglectable [40]. Meanwhile, poor sleep health also shows secular trends alongside changes in modern society and is an under-appreciated determinant of health status. Our study suggested that lifestyle changes including sleeping would help to reduce the burden and associated costs of MetS, subsequently improving health-related quality of life, especially for older men with short sleep durations. Randomized control trials are warranted to examine the effectiveness and cost-effectiveness of sleep-related behavior changes and the risk of MetS.

Our study was the first epidemiological study assessing the association between sleep durations of the aged and MetS in Chinese older adults. In addition, we performed a gender-stratified analysis to reveal the differential associations between sleep durations and MetS in men and women. However, several limitations of the study should be noted. First, sleep durations at night might also be affected by sleep disorders and carbohydrate intake which may have an impact on MetS [41, 42], so we were not able to evaluate all of such confounders. Second, we cannot determine a causal relationship between sleep durations and MetS due to the cross-sectional design in nature. It is also likely that patients with MetS tended to sleep more [43]. MetS-related changes in the concentration of metabolites might destroy the systemic homeostasis of human system and ultimately result in physiological disorders [44]. In addition, insulin resistance is a key link and common pathogenesis of various metabolic abnormalities in MetS. Altered insulin and glucose metabolism would lead to the loss of energy, which may cause fatigue and result in long sleep durations [45]. It is possible that the association between sleep and MetS are bidirectional and warrants further clarifications [46, 47]. Third, information regarding sleep-related parameters and lifestyle habits were collected by self-reported questionnaires which may be subjected to information bias. However, a previous study found that the agreement between objective and subjective measures of sleep-related parameters was relatively good [48].

In conclusion, sleep durations at night might have a dual effect on the risk of MetS and this effect was particularly pronounced in men. The results indicated that circadian rhythm might play an important role in the development of MetS in Chinese older populations. Longitudinal cohort studies with the objective measurement of sleep-related parameters are warranted to verify the association.

Acknowledgements This study was supported by the Science and Technology Bureau of Xiangcheng District in Suzhou, China under grant no. XJ201706 and the Health Commission of Suzhou under grant no. GSWS2019090.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study was conducted abide by the tenets of the Helsinki Declaration, and with the approval of the Institutional Review Board of Soochow University.

References

1. J.A. Batsis, R.E. Nieto-Martinez, F. Lopez-Jimenez, Metabolic syndrome: from global epidemiology to individualized medicine. Clin. Pharm. Ther. **82**(5), 509–524 (2007). https://doi.org/10.1038/sj.clpt.6100355
2. M. Mongraw-Chaffin, M.C. Foster, C.A.M. Anderson, G.L. Burke, N. Haq, R.R. Kalyani, P. Ouyang, C.T. Sibley, R. Tracy, M. Woodward, D. Vaidya, Metabolically healthy obesity, transition to metabolic syndrome, and cardiovascular risk. J. Am. Coll. Cardiol. **71** (17), 1857–1865 (2018). https://doi.org/10.1016/j.jacc.2018.02.055
3. T.P. Ng, L. Feng, M.S. Nyunt, L. Feng, Q. Gao, M.L. Lim, S.L. Collinson, M.S. Chong, W.S. Lim, T.S. Lee, P. Yap, K.B. Yap, Metabolic syndrome and the risk of mild cognitive impairment and progression to dementia: follow-up of the Singapore longitudinal ageing study cohort. JAMA Neurol. **73**(4), 456–463 (2016). https://doi.org/10.1001/jamaneurol.2015.4899
4. V. Xanthakis, J.H. Sung, T.E. Samdarshi, A.N. Hill, S.K. Musani, M. Sims, K.A. Ghraibeh, P.R. Liebson, H.A. Taylor, R.S. Vasan, E.R. Fox, Relations between subclinical disease markers and type 2 diabetes, metabolic syndrome, and incident cardiovascular disease: the Jackson Heart Study. Diabetes Care **38**(6), 1082–1088 (2015). https://doi.org/10.2337/dc14-2460
5. T. Ma, G. Shi, Y. Zhu, Y. Wang, X. Chu, X. Jiang, Z. Liu, J. Cai, H. Wang, L. Jin, Z. Wang, X. Wang, Sleep disturbances and risk of falls in an old Chinese population-Rugao Longevity and Ageing Study. Arch. Gerontol. Geriatr. **73**, 8–14 (2017). https://doi.org/10.1016/j.archger.2017.07.003
6. C.L. Lin, C.P. Lin, S.W. Chen, H.C. Wu, Y.H. Tsai, The association between sleep duration and overweight or obesity in Taiwanese adults: a cross-sectional study. Obes. Res. Clin. Pract. **12** (4), 384–388 (2018). https://doi.org/10.1016/j.orcp.2016.07.005
7. R. Liu, Y. Li, Z. Mao, X. Liu, H. Zhang, K. Yang, H. Zhang, R. Tu, X. Qian, J. Jiang, R. Bie, C. Wang, Gender-specific independent and combined dose-response association of napping and night sleep duration with type 2 diabetes mellitus in rural Chinese adults: the RuralDiab study. Sleep Med. **45**, 106–113 (2018). https://doi.org/10.1016/j.sleep.2017.12.017
8. Y. Zhan, R. Chen, J. Yu, Sleep duration and abnormal serum lipids: the China Health and Nutrition Survey. Sleep Med. **15**(7), 833–839 (2014). https://doi.org/10.1016/j.sleep.2014.02.006
9. X. Li, L. Lin, L. Lv, X. Pang, S. Du, W. Zhang, G. Na, H. Ma, Q. Zhang, S. Jiang, H. Deng, T. Han, C. Sun, Y. Li, U-shaped relationships between sleep duration and metabolic syndrome and metabolic syndrome components in males: a prospective cohort study. Sleep Med. **16**(8), 949–954 (2015). https://doi.org/10.1016/j.sleep.2015.03.024
10. L. Pulido-Arjona, J.E. Correa-Bautista, C. Agostinis-Sobrinho, J. Mota, R. Santos, M. Correa-Rodriguez, A. Garcia-Hermoso, R. Ramirez-Velez, Role of sleep duration and sleep-related problems in the metabolic syndrome among children and adolescents. Ital. J. Pediatr. **44**(1), 9 (2018). https://doi.org/10.1186/s13052-018-0451-7
11. M.H. Hall, M.F. Muldoon, J.R. Jennings, D.J. Buysse, J.D. Flory, S. B. Manuck, Self-reported sleep duration is associated with the metabolic syndrome in midlife adults. Sleep **31**(5), 635–643 (2008)
12. T. Ohkuma, H. Fujii, M. Iwase, S. Ogata-Kaizu, H. Ide, Y. Kikuchi, Y. Idewaki, T. Jodai, Y. Hirakawa, U. Nakamura, T. Kitazono, U-shaped association of sleep duration with metabolic syndrome and insulin resistance in patients with type 2 diabetes: the Fukuoka Diabetes Registry. Metabolism **63**(4), 484–491 (2014). https://doi.org/10.1016/j.metabol.2013.12.001
13. K.M. Choi, J.S. Lee, H.S. Park, S.H. Baik, D.S. Choi, S.M. Kim, Relationship between sleep duration and the metabolic syndrome: Korean National Health and Nutrition Survey 2001. Int. J. Obes. **32**(7), 1091–1097 (2008). https://doi.org/10.1038/ijo.2008.62

14. C.E. Kim, S. Shin, H.W. Lee, J. Lim, J.K. Lee, A. Shin, D. Kang, Association between sleep duration and metabolic syndrome: a cross-sectional study. BMC Public Health **18**(1), 720 (2018). https://doi.org/10.1186/s12889-018-5557-8
15. K.M. Stefani, H.C. Kim, J. Kim, K. Oh, I. Suh, The influence of sex and age on the relationship between sleep duration and metabolic syndrome in Korean adults. Diabetes Res. Clin. Pract. **102**(3), 250–259 (2013). https://doi.org/10.1016/j.diabres.2013.10.003
16. D. Saleh, I. Janssen, Interrelationships among sedentary time, sleep duration, and the metabolic syndrome in adults. BMC Public Health **14**, 666 (2014). https://doi.org/10.1186/1471-2458-14-666
17. S.D. Youngstedt, E.E. Goff, A.M. Reynolds, D.F. Kripke, M.R. Irwin, R.R. Bootzin, N. Khan, G. Jean-Louis, Has adult sleep duration declined over the last 50+ years? Sleep Med. Rev. **28**, 69–85 (2016). https://doi.org/10.1016/j.smrv.2015.08.004
18. O.E. Titova, E. Lindberg, S. Elmstahl, L. Lind, H.B. Schioth, C. Benedict, Associations between the prevalence of metabolic syndrome and sleep parameters vary by age. Front. Endocrinol. **9**, 234 (2018). https://doi.org/10.3389/fendo.2018.00234
19. A. Martocchia, M. Stefanelli, G.M. Falaschi, L. Toussan, C. Ferri, P. Falaschi, Recent advances in the role of cortisol and metabolic syndrome in age-related degenerative diseases. Aging Clin. Exp. Res. **28**(1), 17–23 (2016). https://doi.org/10.1007/s40520-015-0353-0
20. M. Kumari, E. Badrick, T. Chandola, N.E. Adler, E. Epel, T. Seeman, C. Kirschbaum, M.G. Marmot, Measures of social position and cortisol secretion in an aging population: findings from the Whitehall II study. Psychosom. Med. **72**(1), 27–34 (2010). https://doi.org/10.1097/PSY.0b013e3181c85712
21. X. Chen, R. Wang, P. Zee, P.L. Lutsey, S. Javaheri, C. Alcantara, C.L. Jackson, M.A. Williams, S. Redline, Racial/ethnic differences in sleep disturbances: the Multi-Ethnic Study of Atherosclerosis (MESA). Sleep **38**(6), 877–888 (2015). https://doi.org/10.5665/sleep.4732
22. X. Hou, J. Lu, J. Weng, L. Ji, Z. Shan, J. Liu, H. Tian, Q. Ji, D. Zhu, J. Ge, L. Lin, L. Chen, X. Guo, Z. Zhao, Q. Li, Z. Zhou, G. Shan, Z. Yang, W. Yang, W. Jia, Impact of waist circumference and body mass index on risk of cardiometabolic disorder and cardiovascular disease in Chinese adults: a national diabetes and metabolic disorders survey. PLoS ONE **8**(3), e57319 (2013). https://doi.org/10.1371/journal.pone.0057319
23. W. Li, F. Song, X. Wang, L. Wang, D. Wang, X. Yin, S. Cao, Y. Gong, W. Yue, F. Yan, H. Zhang, Z. Sheng, Z. Wang, Z. Lu, Prevalence of metabolic syndrome among middle-aged and elderly adults in China: current status and temporal trends. Ann. Med. **50**(4), 345–353 (2018). https://doi.org/10.1080/07853890.2018.1464202
24. J. Lu, L. Wang, M. Li, Y. Xu, Y. Jiang, W. Wang, J. Li, S. Mi, M. Zhang, Y. Li, T. Wang, M. Xu, Z. Zhao, M. Dai, S. Lai, W. Zhao, L. Wang, Y. Bi, G. Ning, Metabolic syndrome among adults in China: the 2010 China noncommunicable disease surveillance. J. Clin. Endocrinol. Metab. **102**(2), 507–515 (2017). https://doi.org/10.1210/jc.2016-2477
25. C.W. Pan, X.L. Cong, H.J. Zhou, X.Z. Wang, H.P. Sun, Y. Xu, P. Wang, Evaluating health-related quality of life impact of chronic conditions among older adults from a rural town in Suzhou, China. Arch. Gerontol. Geriatr. **76**, 6–11 (2018). https://doi.org/10.1016/j.archger.2018.01.008
26. Y.J. Gu, C.H. He, S. Li, S.Y. Zhang, S.Y. Duan, H.P. Sun, Y.P. Shen, Y. Xu, J.Y. Yin, C.W. Pan, Tea consumption is associated with cognitive impairment in older Chinese adults. Aging Ment. Health **22**(9), 1232–1238 (2018). https://doi.org/10.1080/13607863.2017.1339779
27. C.W. Pan, X. Wang, Q. Ma, H.P. Sun, Y. Xu, P. Wang, Cognitive dysfunction and health-related quality of life among older Chinese. Sci. Rep. **5**, 17301 (2015). https://doi.org/10.1038/srep17301
28. C. Sabanayagam, J.J. Wang, P. Mitchell, A.G. Tan, E.S. Tai, T. Aung, S.M. Saw, T.Y. Wong, Metabolic syndrome components and age-related cataract: the Singapore Malay eye study. Investig. Ophthalmol. Vis. Sci. **52**(5), 2397–2404 (2011). https://doi.org/10.1167/iovs.10-6373
29. B. Xi, D. He, M. Zhang, J. Xue, D. Zhou, Short sleep duration predicts risk of metabolic syndrome: a systematic review and meta-analysis. Sleep. Med. Rev. **18**(4), 293–297 (2014). https://doi.org/10.1016/j.smrv.2013.06.001
30. J.Y. Kim, D. Yadav, S.V. Ahn, S.B. Koh, J.T. Park, J. Yoon, B.S. Yoo, S.H. Lee, A prospective study of total sleep duration and incident metabolic syndrome: the ARIRANG study. Sleep Med. **16**(12), 1511–1515 (2015). https://doi.org/10.1016/j.sleep.2015.06.024
31. J.P. Chaput, J. McNeil, J.P. Despres, C. Bouchard, A. Tremblay, Seven to eight hours of sleep a night is associated with a lower prevalence of the metabolic syndrome and reduced overall cardiometabolic risk in adults. PLoS ONE **8**(9), e72832 (2013). https://doi.org/10.1371/journal.pone.0072832
32. L.X. Yan, X.R. Chen, B. Chen, Y.M. Bai, J.H. Li, X.W. Zhang, Z. Dong, H. Wang, S.Q. Mi, W.H. Zhao, Gender-specific association of sleep duration with body mass index, waist circumference, and body fat in Chinese adults. Biomed. Environ. Sci. **30**(3), 157–169 (2017). https://doi.org/10.3967/bes2017.023
33. H.B. Deng, T. Tam, B.C. Zee, R.Y. Chung, X. Su, L. Jin, T.C. Chan, L.Y. Chang, E.K. Yeoh, X.Q. Lao. Short sleep duration increases metabolic impact in healthy adults: a Population-Based Cohort Study. Sleep **40**(10) (2017). https://doi.org/10.1093/sleep/zsx130
34. J. Xiao, C. Wu, G. Xu, J. Huang, Y. Gao, Q. Lu, T. Hua, H. Cai, Association of physical activity with risk of metabolic syndrome: findings from a cross-sectional study conducted in rural area, Nantong, China. J. Sports Sci. **34**(19), 1839–1848 (2016). https://doi.org/10.1080/02640414.2016.1140221
35. K.V. Hjerkind, J.S. Stenehjem, T.I. Nilsen, Adiposity, physical activity and risk of diabetes mellitus: prospective data from the population-based HUNT study, Norway. BMJ Open **7**(1), e013142 (2017). https://doi.org/10.1136/bmjopen-2016-013142
36. M.L. Andersen, T.F. Alvarenga, R. Mazaro-Costa, H.C. Hachul, S. Tufik, The association of testosterone, sleep, and sexual function in men and women. Brain Res. **1416**, 80–104 (2011). https://doi.org/10.1016/j.brainres.2011.07.060
37. J.R. Carter, J.J. Durocher, R.A. Larson, J.P. DellaValla, H. Yang, Sympathetic neural responses to 24-hour sleep deprivation in humans: sex differences. Am. J. Physiol. Heart Circ. Physiol. **302**(10), H1991–H1997 (2012). https://doi.org/10.1152/ajpheart.01132.2011
38. A.E. Reschke-Hernandez, K.L. Okerstrom, A. Bowles Edwards, D. Tranel, Sex and stress: men and women show different cortisol responses to psychological stress induced by the Trier social stress test and the Iowa singing social stress test. J. Neurosci. Res. **95**(1–2), 106–114 (2017). https://doi.org/10.1002/jnr.23851
39. C.W. Pan, Q. Ma, H.P. Sun, Y. Xu, N. Luo, P. Wang, Tea Consumption and Health-Related Quality of Life in Older Adults. J. Nutr. Health Aging **21**(5), 480–486 (2017). https://doi.org/10.1007/s12603-016-0784-0
40. M. Liu, J. Wang, B. Jiang, D. Sun, L. Wu, S. Yang, Y. Wang, X. Li, Y. He, Increasing prevalence of metabolic syndrome in a Chinese elderly population: 2001–2010. PLoS ONE **8**(6), e66233 (2013). https://doi.org/10.1371/journal.pone.0066233
41. S.M. Johari, S. Shahar, Metabolic syndrome: the association of obesity and unhealthy lifestyle among Malaysian elderly people. Arch. Gerontol. Geriatr. **59**(2), 360–366 (2014). https://doi.org/10.1016/j.archger.2014.04.003
42. N. Okubo, M. Matsuzaka, I. Takahashi, K. Sawada, S. Sato, N. Akimoto, T. Umeda, S. Nakaji, Relationship between self-reported sleep quality and metabolic syndrome in general

population. BMC Public Health **14**, 562 (2014). https://doi.org/10.1186/1471-2458-14-562
43. E.N. Georgousopoulou, N.M. D'Cunha, D.D. Mellor, S. Tyrovolas, N. Naumovski, A. Foscolou, V. Bountziouka, E. Gotsis, G. Metallinos, D. Tyrovola, S. Piscopo, G. Valacchi, N. Tsakountakis, A. Zeimbekis, J.-A. Tur, A.-L. Matalas, E. Polychronopoulos, C. Lionis, L. Sidossis, D.B. Panagiotakos, M.S. Group, The Association Between sleeping time and metabolic syndrome features, among older adults living in Mediterranean region: the MEDIS Study. Metab. Syndr. Relat. Disord. **16**(1), 20–28 (2018). https://doi.org/10.1089/met.2017.0113
44. Y. Cao, R.H. Wang, Associations among metabolism, circadian rhythm and age-associated diseases. Aging Dis. **8**(3), 314–333 (2017). https://doi.org/10.14336/ad.2016.1101
45. A.J. Pyykkonen, B. Isomaa, A.K. Pesonen, J.G. Eriksson, L. Groop, T. Tuomi, K. Raikkonen, Sleep duration and insulin resistance in individuals without type 2 diabetes: the PPP-Botnia study. Ann. Med. **46**(5), 324–329 (2014). https://doi.org/10.3109/07853890.2014.902226
46. V.H. Goh, T.Y. Tong, Sleep, sex steroid hormones, sexual activities, and aging in Asian men. J. Androl. **31**(2), 131–137 (2010). https://doi.org/10.2164/jandrol.109.007856
47. D. Morgan, S.C. Tsai, Sleep and the endocrine system. Crit. Care Clin. **31**(3), 403–418 (2015). https://doi.org/10.1016/j.ccc.2015.03.004
48. S.W. Lockley, D.J. Skene, J. Arendt, Comparison between subjective and actigraphic measurement of sleep and sleep rhythms. J. Sleep Res. **8**(3), 175–183 (1999)