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Sleep duration, daytime napping and the risk of incident metabolic syndrome vary by age and sex: findings from the China health and retirement longitudinal study

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Abstract

Objective Currently, the association of sleep duration and daytime napping with the prevalence of metabolic syndrome (MetS) is still controversial. This study was designed to explore the association between sleep duration, daytime napping and MetS by age and sex in Chinese adults.

Methods Data were obtained from the 2011 and 2015 waves of the China Health and Retirement Longitudinal Study (CHARLS). Participants with MetS at baseline or with missing data were excluded, leaving 2803 participants (≥ 45 years old) who completed follow-up and were included in the longitudinal analysis. Sleep duration and daytime napping were determined by self-reported questionnaires. Medical conditions, including MetS, dyslipidaemia, hypertension, and diabetes mellitus, were determined from a fasting blood specimen and physical exam at the baseline visit. Logistic regression models were performed to explore the longitudinal associations of baseline napping and sleep duration with MetS and its occurrence.

Results During a median follow-up period of 4 years, 616 participants (22.0%) developed new-onset MetS. Compared with non-napping, longer daytime napping (> 30 min/day) was significantly associated with the occurrence of MetS (OR: 1.247, 95% CI: 1.001, 1.554), and a significant association was still present after adjustment for each of the covariates. In the subgroup analysis, longer daytime napping (> 30 min/day) was also significantly associated with MetS in elderly females (OR: 1.946, 95% CI: 1.226, 3.090). Moreover, sleep duration was not significantly associated with MetS in our study.

Conclusion A longer napping duration is associated with an increased risk of MetS in an older Chinese population, and this association differed according to sex.

Keywords Sleep duration, Daytime napping, Metabolic syndrome, Prospective cohort study

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Introduction

Metabolic syndrome (MetS) is not a strictly disease but a complex set of clinical symptoms; it includes hypertension, hyperlipidaemia, hyperglycaemia, and central obesity [1]. In recent years, due to the ageing of the population and lifestyle changes, the incidence rate of MetS in the world is 20 ~ 45%, which is expected to increase to approximately 53% in 2035 [2]. Given its high prevalence rates in China, approximately 24.2% among adults throughout the last decade, the identification of modifiable risk factors associated with MetS and its components is important to public health [3].

Sleep plays an important role in human physical health, cognition, memory and longevity [4, 5]. In China, daytime napping is very common and is often considered a healthy lifestyle; it can provide benefits such as fatigue relief, memory consolidation and cognitive enhancement [6, 7]. However, many studies have found that daytime napping and sleep duration were also associated with mortality risk [8] and illnesses ranging from psychiatric disorders [9] and somatic disorders [10, 11]. In addition, insufficient or excessive sleep can lead to maladaptive changes and metabolic disorders, such as MetS, hypertension, cardiovascular disease, diabetes and obesity [12–15]. Based on previous research [16–19], we have summarized some of the putative relationships between sleep parameters and MetS as illustrated in Fig. 1.

Despite the high prevalence of napping in China, its association with MetS has received less attention. Moreover, due to differences in the classification criteria for daytime naps in existing studies, there is heterogeneity in the relationship between daytime sleep and the risk

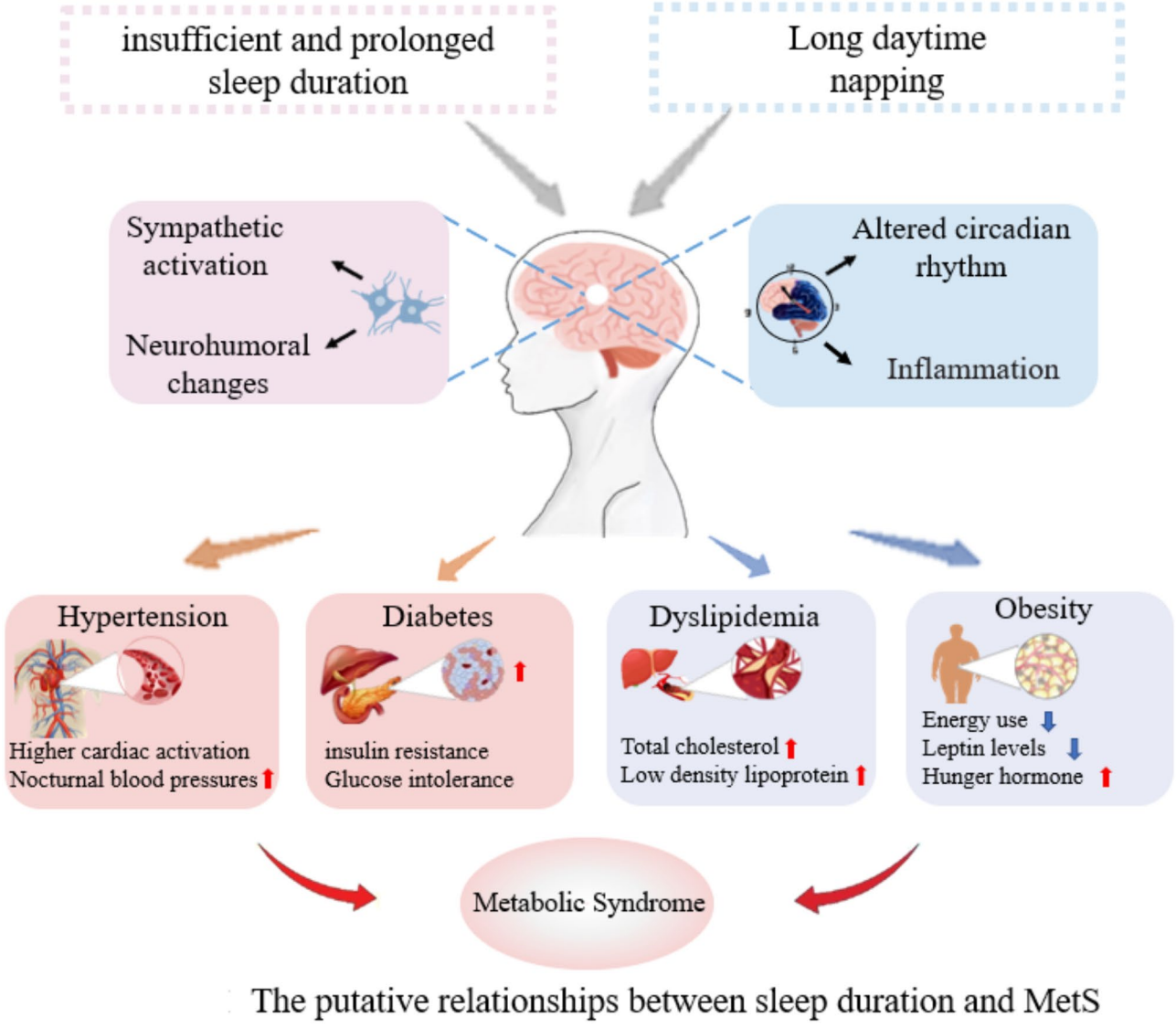

Fig. 1 The putative relationships between sleep duration and MetS

of MetS [20–22]. On the other hand, althought previous studies showed that sleep duration (either too short or too long) was associated with a high incidence of MetS [23–25], a study showed that a short sleep duration rather than long was associated with the risk of MetS [26]. Moreover, some studies have found that the association between longer sleep duration and MetS was observed only in 36- to 50 year-olds [27], and short sleep duration was only associated with a high incidence of MetS in women [28]. These inconsistent findings may be because sleep is multidimensional and heterogeneous according to age and sex.

However, to the best of our knowledge, the effects of age and sex on the relationship between sleep parameters and the incidence of MetS have not been fully elucidated, and have received less attention. In this study, we used data from a large nationally representative sample in mainland China to compare associations between sleep duration and MetS in different age and sex groups. Furthermore, we also excluded the interference of confounding factors such as sleep quality and other demographic variables to better understand the sleep–MetS relationship. Given the high prevalence of sleep problems and MetS in modern society, this study could contribute to the growing knowledge on the possible relationship between circadian rhythms and MetS and its related complications in different populations.

Materials and methods

Study sample

CHARLS is a national population-based survey of community-dwelling adults aged 45 years and older including 10,287 households, 17,708 individuals, and covering 150 counties in 28 provinces; the survey has been used to gather information with a focus on the health and socioeconomic status of the rapidly ageing population. The first wave was conducted between June 2011 and March 2012, and the participants were followed up biennially until wave 4 in 2018 [29].

Participants who were aged 45 years or older, had undergone a comprehensive medical examination at baseline in 2011, and subsequently had their results reassessed four years later in 2015, were screened for inclusion. At baseline, people with MetS and lacking necessary data (such as blood samples, age and sex) were excluded from the study, and a total of 6018 participants were included. At the follow-up visit, 1909 participants did not attend the follow up survey or were without blood sample examination, and 1306 participants were excluded due to missing information on MetS, yielding a final sample of 2803 participants. More details on the inclusion process of the study sample can be seen in Fig. 2.

Sleep duration and daytime napping

Sleep duration and daytime napping were determined by self-report questionnaires. Nighttime sleep duration was assessed by the following question: "During the past month, how many hours of actual sleep did you get every night? (mean hours per night)". In 2015, the American Academy of Sleep Medicine and Sleep Research Society recommended that the optimal sleep time for adults was at least 7 h. Sleep less than 6 h per night was considered sleep deprivation, and sleep more than 9 h per night was considered excessive sleep [30]. Therefore, sleep duration was stratified into three groups: short (≤6 h/day), normal (7–8 h/day) and long (≥9 h/day). Daytime napping was assessed by asking "During the past month, how long did you take naps after lunch?" According to previous

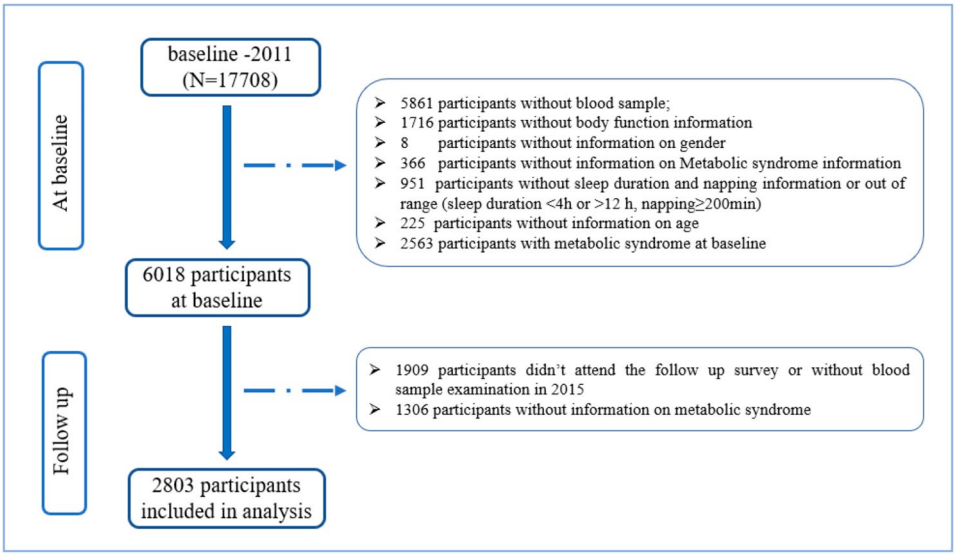

Fig. 2 Flowchart of the sample selection process

studies, individuals were categorized into three groups: no napping, 0–30 min (not including 0), and >30 min napping. Therefore, we used nighttime sleep duration of 7–8 h/night and daytime napping of 0–30 min/day as definitions for the control groups. Sleep quality was assessed by asking "Have you ever had sleep restless in the past week?" and stratified into good (≤2 days) and poor (3–7 days).

Definition of metabolic syndrome

According to the Chinese Guidelines for the Prevention and Treatment of Type 2 Diabetes (2017 edition) [31], MetS was diagnosed when 3 or more of the following criteria were met: (1) abdominal obesity—waist circumference ≥90 cm for men and ≥85 cm for women; (2) high blood glucose—fasting plasma glucose level ≥6.1 mmol/L or 2-hour plasma glucose (2hPG) level ≥7.8 mmol/L or previously diagnosed type 2 diabetes; (3) high blood pressure—blood pressure ≥130/85 mm/Hg or drug treatment for hypertension; (4) high triglycerides (TG)—fasting triglyceride level ≥1.70 mmol/L; and (5) low high density lipoprotein cholesterol (HDL-C)—HDL-C level <1.04 mmol/L.

Covariate variables

Information on clinical or biochemical measures, sociodemographic characteristics, lifestyle behaviors and cognitive and depression assessments was collected at baseline. Clinical/biochemical measures included the self-reported diagnosis of dyslipidaemia, hypertension, diabetes or high blood glucose, waist circumference (WC), systolic blood pressure (SBP), diastolic blood pressure (DBP), total cholesterol (TC), TG, low-density lipoprotein cholesterol (LDL-C), HDL-C and fasting plasma glucose (FPG). Sociodemographic characteristics included age, sex, marital status (married/divorced /unmarried), education level (illiterate/specialist and below/ bachelor's degree or above), and area of residence (rural/urban). Lifestyle behaviors included smoking status (yes/no), drinking status (never/quit/current) and self-reported health status (good/fair/poor). Moreover, age was dichotomized: middle-aged people aged 45–59 years old and elderly people aged 60 years old and older.

Statistical analysis

Data analyses were conducted in SPSS version 25.0 (SPSS Inc, Chicago, IL) and R version 4.1.3 (https://www.r-project.org/) software. Continuous variables were presented as the mean ± standard deviation and categorical variables were presented as the frequency and percentage. The Chi-squared test and Student's t-test were used to compare the differences in baseline characteristics of participants with and without incident MetS for categorical and continuous variables, respectively. Three multivariate logistic regression models were used to determine independent associations between nighttime sleep duration and daily naps with MetS. The odds ratios (ORs) and 95% confidence intervals (CIs) were calculated to assess the effects of sleep duration and daytime napping on the risk of MetS. The statistical significance level was set at $\alpha = 0.05$ (two-tailed).

Results

Participant characteristics

Table 1 shows the main baseline characteristics of the study population ($N = 2803$) stratified by MetS status. A total of 2803 participants (1221 males and 1582 females) with an average age of 58.24 ± 8.59 years were included in this study. Participants with ≤6, 7–8 and ≥9 h of sleep accounted for 45.8% ($n = 1285$), 45.4% ($n = 1273$), and 8.7% ($n = 245$) of the cohort, respectively. Over half of the population (53.8%) took a nap during the daytime, and 37.2% took longer napping (>30 min). On follow-up (mean of 4 years), new-onset MetS developed in 616 (22.0%) participants (mean age 58.24 ± 8.59). Compared to MetS-free participants, those with MetS were older, in poorer health, and exhibited significantly elevated levels of SBP, DBP, WC, TG, TC, and LDL-C. Additionally, they had reduced levels of HDL-C. All differences were statistically significant ($P < 0.05$). Moreover, the prevalence of MetS was higher among people with stroke, digestive system diseases, and chronic obstructive pulmonary disease (COPD). We also observed a significantly higher rate of MetS in women than in men (23.9% vs. 19.5%).

Sleep parameters and metabolic syndrome

The prevalence of MetS and its components also varied in different daytime napping and nighttime sleep duration groups. We found a higher prevalence of patients with MetS, central obesity, high FPG and hypertension in the groups with longer daytime napping (in Supplementary Fig. 1). In particular, we found a significant correlation between MetS, central obesity and daytime napping, but this association was not found in other components of MetS. We also found that a higher prevalence of patients with high TG and low LDL-C was observed in the groups with longer sleep duration.

Further multivariate regression analysis confirmed that individuals with longer daytime napping (>30 min/day) were at an increased risk of MetS (OR: 1.247, 95% CI: 1.001, 1.554) compared with individuals who did not nap. A significant association was still present after adjustment for each of the covariates. However, there were no significant associations between short and long sleep duration and incident MetS, compared with sleep duration of 7–8 h/night; nor were there any significant association between shorter napping (0–30 min/day) and

Table 1 Baseline characteristics of the study population with and without MetS

Variables	Total	Without MetS	With MetS	*P*
	(n = 2803)	(n = 2187)	(n = 616)	
Sociodemographic characteristics				
Age	58.24 ± 8.59	58.18 ± 8.54	58.44 ± 8.76	0.636
Gender				0.006
man	1221(43.6%)	983(44.9%)	238(38.6%)	
woman	1582(56.4%)	1204(55.1%)	378(61.4%)	
Education level				0.191[a]
illiterate	760(27.1%)	584(26.7%)	176(28.6%)	
specialist and below	2039(72.7%)	1601(73.2%)	438(71.1%)	
bachelor degree or above	4(0.1%)	2(0.1%)	2(0.3%)	
Marital status				0.489 [a]
married	2540(90.6%)	1984(90.7%)	556(90.3%)	
divorced/widowed	245(8.7%)	187(8.6%)	58(9.4%)	
unmarried	18(0.6%)	16(0.7%)	2(0.3%)	
Residence (urban)	2345(83.7%)	1843(84.3%)	502(81.6%)	0.123
Lifestyle factors				
Smoking (yes)	1028(36.7%)	802(36.7%)	266(36.7%)	1
Drinking status				0.021
current	697(24.9%)	552(25.2%)	145(23.5%)	
quit	221(7.9%)	187(8.6%)	34(5.5%)	
never	1885(67.2%)	1448(66.2%)	437(70.9%)	
Sleep duration(h/day)				0.24
≤ 6	1273(45.4%)	1011(45.0%)	262(42.5%)	
07-Aug	1285(45.8%)	985(46.2%)	300(48.7%)	
≥ 9	245(8.7%)	191(8.7%)	54(8.8.%)	
Daytime napping(min/day)				0.027
0	1297(46.3%)	1036(47.4%)	261(42.4%)	
0–30	464(16.6%)	366(16.7%)	98(15.9%)	
> 30	1042(37.2%)	785(35.9%)	257(41.7%)	
Sleep quality				0.151
good	1939(69.4%)	1498(68.8%)	441(71.8%)	
poor	853(30.6%)	680(31.2%)	173(28.2%)	
Clinical characteristics				
COPD (yes)	278(10.0%)	230(10.6%)	48(7.8%)	0.047
Disability (yes)	82(2.9%)	65(3.0%)	17(2.8%)	0.791
Stroke (yes)	48(1.7%)	29(1.3%)	19(3.1%)	0.005
Heart diseases (yes)	327(11.7%)	243(11.2%)	84(13.7%)	0.102
Digestive diseases (Yes)	612(21.9%)	503(23.1%)	109(17.7%)	0.005
Self-rated health				0.217
good	685(24.4%)	537(24.6%)	148(24.0%)	
fair	1379(49.2%)	1090(49.8%)	289(46.9%)	
poor	739(26.4%)	560(25.6%)	179(29.1%)	

incident MetS, compared with no napping. The ORs of MetS and sleep parameters are shown in Table 2.

Subgroup analysis

Therefore, we stratified and compared the data based on gender and age. When stratified by gender and age, significant differences in nap behavior and MetS were observed among different gender and age groups (Please refer to Supplementary Tables 1–2 for detailed information). Consequently, we further conducted multivariate analysis. As Table 3 shows, longer daytime napping (OR: 1.661, 95% CI: 1.173, 2.353) was associated with MetS among elderly people. In addition, further analysis in the elderly population revealed that longer daytime napping in females (OR: 1.946, 95% CI: 1.226, 3.090), but not males (OR: 1.375, 95% CI: 0.792, 2.388) was associated with the risk of MetS. Among middle-aged people, however, the associations between daytime napping and MetS were not significant after adjustment for confounders. In

Table 2 Odds ratios (95%CI) of incident MetS by sleep duration and daytime napping

Variables	Unadjusted model	Multivariable adjusted[1]	Multivariable adjusted[2]
sleep duration			
≤6	0.872(0.722,1.053)	0.852(0.704,1.031)	0.943(0.758,1.172)
7–8	1	1	1
≥9	0.923(0.664,1.283)	0.901(0.647,1.253)	0.826(0.573,1.192)
daytime napping			
0	1	1	1
0–30	1.063(0.819,1.381)	1.082(0.833,1.406)	1.024(0.767,1.366)
>30	**1.282(1.053,1.561) ***	**1.339(1.097,1.633) ***	**1.247(1.001,1.554) ***

Abbreviations: CI, confidence interval; OR, Odds ratio; *: $P<0.05$

[1]: Adjusted for age, gender

[2]: Adjusted for age, gender, history of stroke, COPD, disability, heart diseases, and digestive diseases, smoking status, drinking status and area of residence, sleep quality, Self-rated health, TC, TG, HDL, LDL, FPG, SBP, DBP

Table 3 Relationship between sleep parameters and MetS stratified by age groups

Variables	Age < 60years		Age ≥ 60years	
	Model1	Model2	Model1	Model2
sleep duration				
≤6	0.912(0.713,1.166)	1.078(0.809,1.437)	0.817 (0.608,1.098)	0.802(0.568,1.133)
7–8	1	1	1	1
≥9	0.851(0.541,1.338)	0.768(0.460,1.283)	0.992(0.611,1.610)	0.907(0.521,1.580)
daytime napping				
0	1	1	1	1
0–30	0.994(0.710,1.393)	0.931(0.639,1.357)	1.181 (0.780,1.787)	1.258(0.791,2.001)
>30	1.125(0.869,1.457)	1.031(0.769,1.382)	**1.538 (1.131,2.087)***	**1.661(1.173,2.353)***

Abbreviations: CI, confidence interval; OR, Odds ratio; *: $P<0.05$

Model1: didn't adjust for confounding factors

Model2: Adjusted for age, gender, history of stroke, COPD, disability, heart diseases, and digestive diseases, smoking status, drinking status and area of residence, sleep quality, Self-rated health, TC, TG, HDL, LDL, FPG, SBP, DBP

contrast, we did not find any association between sleep duration and MetS in any age group (Fig. 3).

Discussion

In the prospective study, 616 (22.0%) of the participants experienced incident MetS events after an average four-year follow-up. The prevalence of MetS was higher than that reported in other studies [24, 32], but it was still lower than that in the study by Claire E. Kim et al. [14]. These differences could be related to factors such as regional, population susceptibility and lifestyle differences of local populations. We observed a relationship between longer daytime napping and MetS in Chinese adults. After adjustment for important covariates, individuals with longer daytime napping (>30 min/day) were also at an increased risk of MetS. Innovatively, our study differed from existing studies in that we considered the associations between daytime napping and MetS stratified according to sex and age. We found that longer daytime napping was significantly associated with MetS in older people, but not in middle-aged people. Interestingly, in the subgroup analysis, the associations between daytime napping and MetS were found only in older females. These results added accumulating evidence that sleep parameters may be implicated diversely in the occurrence of MetS by sex and age.

In our study, 55.4% of elderly people and 52.5% of middle-aged people had napping habits, and people with longer daytime napping were also at an increased risk of MetS. The results corroborated previous findings that longer daytime napping was associated with MetS [33, 34]. Longer daytime napping may cause circadian rhythm disorder, which may lead to metabolic and endocrine abnormalities [35]. The biological mechanism pattern is not yet clear, and we have provided some possible explanations. Longer napping may lead to increased sympathetic activity upon, activation of the renin angiotensin system and glucose dysregulation an increase in cortisol levels and increased fat accumulation [36]. Multiple studies have found that daytime naps are associated with various inflammatory markers, such as higher levels of IL-6 and C-reactive protein [37, 38]. Fundamentally, low-grade inflammation is an important mechanism implicated in the etiology, pathogenesis and development of MetS [39].

Similarly, a meta-analysis shows that the relationship between napping time and the risk of diabetes or MetS seems to be described by a J-curve, with a sharp increase in the risk of diabetes or MetS at longer naps

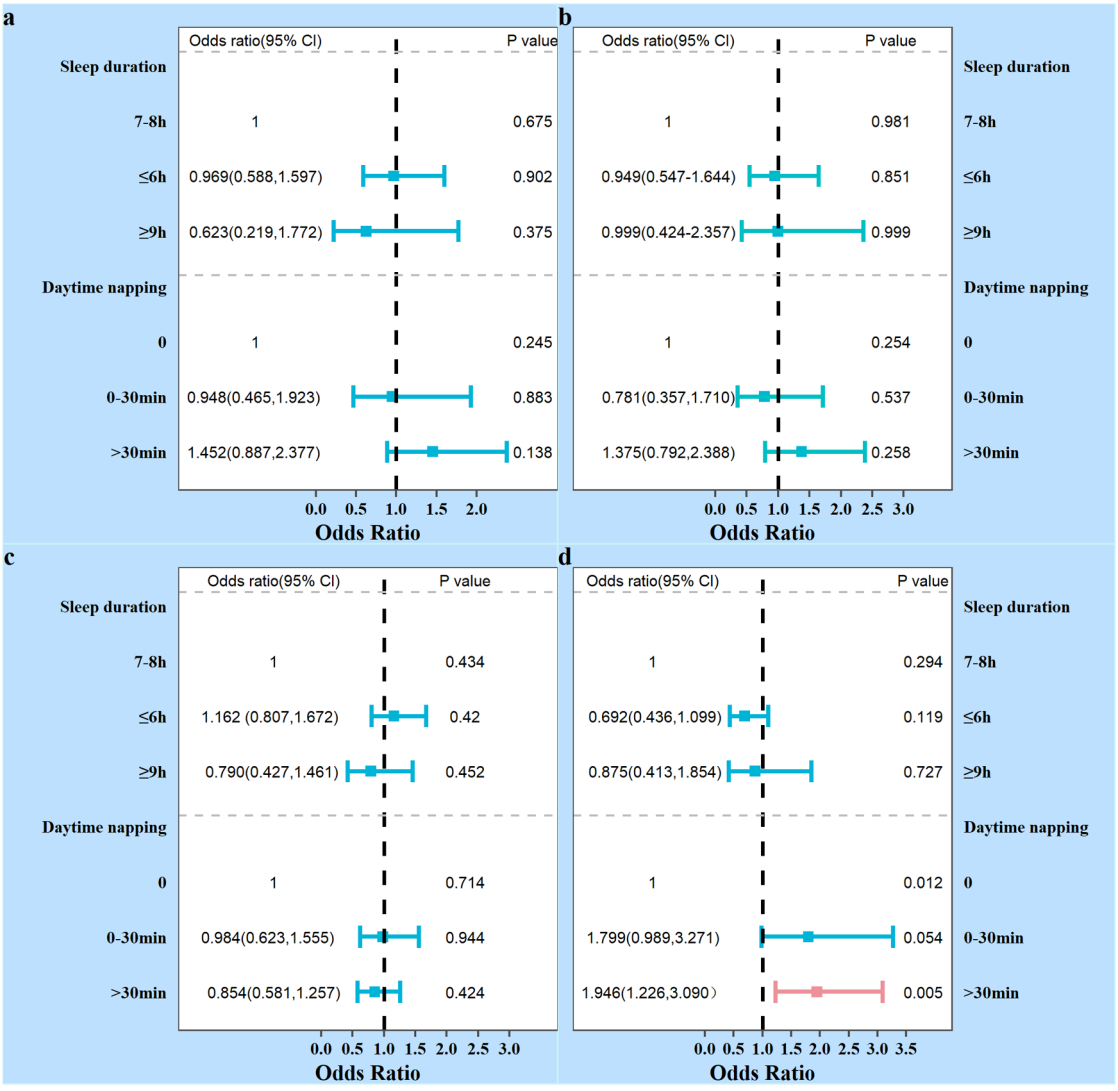

Fig. 3 Relationship between sleep parameters and metabolic syndrome stratified by gender and age. "a" and "b" for males, "a" and for middle-aged, "b" for elderly "c" and "d" for females, "c" and for middle-aged, "d" for elderly Adjusted for age, gender, history of stroke, COPD, disability, heart diseases, and digestive diseases, smoking status, drinking status and area of residence, sleep quality, self-rated health, TC, TG, HDL, LDL, FPG, SBP, DBP

[22]. Increased sympathetic activity upon awaking from daytime naps, especially prolonged naps, could lead to disruption of the sympathovagal balance, resulting in activation of the renin angiotensin system and a subsequent decrease in pancreatic beta-cell secretion and glucose dysregulation [40]. In addition, some studies also showed that daytime napping was associated with obesity [41, 42]. Long naps may lead to changes in the circadian rhythm, increased cortisol levels, and thus increased fat deposition [42]. Similarly, central obesity was significantly associated with excessive naps in our study. According to these findings, obesity is also a potential underlying biological mechanism explaining the adverse long-term effects of napping on the risk of MetS.

Simultaneously, we also evaluated the associations between daytime napping duration and the occurrence of MetS in different subgroups stratified by age and sex. It was found that there is a connection between daytime naps and MetS in elderly people but not in middle-aged people. This may be because elderly retirees also have more opportunities to nap during the day than those of working age. In the subgroup analysis, it was found only in the female older population. The reasons for sex-specific differences were not clear to us. This may be related to women's physiological characteristics, hormone secretion, and psychological stress factors. To maintain a healthy metabolic state, it is recommended that women pay attention to controlling the duration of their nap time and avoid excessively long nap times. In addition, these

differences may be related to the higher prevalence of hypertension, hyperglycemia, hypertriglyceridemia, and central obesity in older women in our study.

The evidence for the link between sleep duration and MetS is diverse. Although a number of previous studies showed a correlation between MetS and sleep duration, our study did not support the notion that sleep duration was associated with MetS. A study of 2189 Hispanic/Latino adults also found no significant correlation between sleep time and MetS [43]. We speculated that this may be related to the fact that 45.8% of participants had normal sleep duration, and the average sleep time was 6.69 h in our study population. Moreover, the measurements of sleep duration were based on self-reports and not objectively measured, which may lead to recall bias and misclassification of exposure. Moreover, 53.8% had the habit of taking a nap every day in our study. Research has shown that short sleep duration may be mediated by napping, and short nighttime sleep has a protective effect for those who nap during the day [44]. However, our study was not designed to address this specific question, and future studies are needed in this regard.

Strengths and limitations

Our study had several major strengths. First, we confirmed that the incidence of MetS was higher with excessive daytime napping in Chinese individuals based on this cohort study. We evaluated the associations between daytime napping and MetS in different subgroups stratified by age and sex. Finally, in our study, we used a large nationwide representative sample covering over 150 counties in 28 provinces in mainland China. Therefore, our research population is representative, and these results can be extended to the Chinese population. However, there are still limitations in our research. First, the measurements of daytime napping duration, sleep duration, sleep quality, and some health status indicators were based on self-reports and not objectively measured, which may lead to recall bias and misclassification of exposure. Second, we did not collect information on sleep disorders and dimensions such as snoring and sleep apnoea. Although we adjusted for several potential confounders, those unmeasured or residual confounders may still affect our findings.

Conclusion

In our study, we have shown that the incidence of MetS was higher with both longer daytime napping in females and elderly populations. Future research should elucidate the association and potential mechanisms between sleep duration and MetS based on objective sleep indicators, and address the issue of whether normalizing sleep duration can reduce the risk of MetS.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-21915-0.

Supplementary Material 1

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Author contributions

BWZ analyzed the data; drafted, reviewed, and edited the manuscript; and contributed to the discussion; WJL and JRW conducted, designed, and supervised the study; reviewed and edited the manuscript; LLZ and KW contributed to the conceptualization of the research process and critically reviewed the manuscript; BWZ was major contributors to the original draft, and PXW contributed to the study concept and design.

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Data availability

The data that support the findings of this study are available in China Health and Retirement Longitudinal Study (CHARLS), at http://charls.pku.edu.cn/ (accessed on 28 February 2023). Materials are available on request to the corresponding author.

Declarations

Ethics approval and consent to participate

Ethics approval for the CHARLS study was obtained from the Institutional Review Board (IRB) at Peking University. The IRB approval number for the main household survey was IRB00001052-11015 and for the biomarker collection was IRB00001052-11014. Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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