SLEEP DURATION/SLEEP QUALITY

Sleep Duration and Midday Napping with 5-Year Incidence and Reversion of Metabolic Syndrome in Middle-Aged and Older Chinese

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Study Objectives: Prospective evidence on the association of sleep duration and midday napping with metabolic syndrome (MetS) is limited. We aimed to examine the associations of sleep duration and midday napping with risk of incidence and reversion of MetS and its components among a middle-aged and older Chinese population.

Methods: We included 14,399 subjects from the Dongfeng-Tongji (DFTJ) Cohort Study (2008–2013) who were free of coronary heart disease, stroke, and cancer at baseline. Baseline data were obtained by questionnaires and health examinations. Odds ratios (ORs) and 95% confidence interval (CI) were derived from multivariate logistic regression models.

Results: After controlling for potential covariates, longer sleep duration (≥ 9 h) was associated with a higher risk of MetS incidence (OR, 1.29; 95% CI, 1.08–1.55) and lower reversion of MetS (OR, 0.80; 95% CI, 0.66–0.96) compared with sleep duration of 7 to < 8 h; whereas shorter sleep duration (< 6 h) was not related to incidence or reversion of MetS. For midday napping, subjects with longer napping (≥ 90 min) was also associated with a higher risk of MetS incidence and a lower risk of MetS reversion compared with those with napping of 1 to < 30 min (OR, 1.48; 95% CI, 1.05–2.10 and OR, 0.70; 95% CI, 0.52–0.94, respectively). Significance for incidence or reversion of certain MetS components remained in shorter and longer sleepers but disappeared across napping categories.

Conclusions: Both longer sleep duration and longer midday napping were potential risk factors for MetS incidence, and concurrently exert adverse effects on MetS reversion.

Keywords: incidence, metabolic syndrome, midday napping, reversion, sleep duration

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Significance

The current study identifies significant associations of longer sleep duration and midday napping with risk of MetS incidence and reversion among middle-aged and older Chinese. Independent of other risk factors, longer sleepers (≥ 9 h) or longer nap takers (≥ 90 min) exhibited 29% or 48% increased risk of MetS incidence as well as 20% or 30% lower MetS reversion, compared with individuals who reported sleeping 7 to < 8 h or napping 1 to < 30 min. No significant associations were observed between shorter sleep duration (< 6 h) and incidence or reversion of MetS. Our findings underscore the importance of appropriate sleep and nap in the prevention and reversal of MetS.

INTRODUCTION

Metabolic syndrome (MetS) is characterized by a set of cardiometabolic risk factors, including central obesity, dyslipidemia, elevated blood pressure, and impaired fasting glucose.[1] This condition confers an increased risk of cardiovascular diseases, type 2 diabetes, and all-cause mortality.[2–4] In China, the prevalence of MetS is increasing and MetS becomes a major public health concern. The International Collaborative Study of Cardiovascular Disease in Asia reported that the prevalence of MetS was approximately 13.7% among Chinese adults aged 35–74 y.[5] It is therefore important to identify the potential risk factors and provide management strategies.

Both sleep and midday napping are important health-related factors and closely linked to hormonal and metabolic systems.[6,7] A growing body of epidemiological evidence showed that shorter (< 6 h) or longer sleep duration (≥ 9 h) and midday napping (more than 1 h) are independently related to increased risks of MetS and/or its components.[8–10] However, most of the previous studies are cross-sectional and several prospective studies on the relation of sleep duration with MetS incidence have produced heterogeneous findings. Three studies

conducted in Korea and Japan indicated a higher risk of MetS incidence in shorter sleepers, but not in longer sleepers,[11–13] while a recent study reported a U-shaped relationship between sleep hours and the risk of MetS incidence in the general Chinese population.[14] However, the relationship of midday napping with incident MetS has not been confirmed in longitudinal studies. Furthermore, no study has examined the relationship of sleep duration or midday napping on the reversion of MetS and its components.

Therefore, we aimed to explore whether sleep duration or midday napping was independently associated with incidence and reversion of MetS and its components over a 5-y period in a middle-aged and older Chinese population.

METHODS

Study Population

Our research was derived from the Dongfeng-Tongji (DFTJ) Cohort Study launched in 2008 among retired workers of Dongfeng Motor Corporation (DMC) in Shiyan city, Hubei province. The details of the DFTJ cohort have been described

previously.[15] Briefly, the primary aim of the DFTJ cohort was to investigate a wide range of lifestyle, dietary, psychosocial, occupational, environmental, and biochemical factors in relation to the development of chronic diseases. The Retirement Office and the Social Insurance Center at DMC provided a list of the retired workers and invited them to participate in this study. All retired employees are covered by DMC's health-care service system and each participant has a unique medical insurance card number and ID. A total of 27,009 retirees were included in the cohort and agreed to answer questionnaires and performed health examinations between September 2008 and June 2010. Five years later, the participants were invited to the follow-up investigation via telephone. At the follow-up survey, participants repeated questionnaire interview, physical examinations, and blood collection as those in the baseline survey. Among 25.978 individuals (96.2% of those at baseline) who completed the follow-up until October, 2013, we excluded individuals with self-reported coronary heart disease, stroke, or cancer at baseline (n = 5,865) as those with these chronic conditions may spend more time sleeping or napping and thus overestimate the sleep/nap/MetS associations.[8] In addition, we also excluded those with missing information on sleep duration at baseline (n = 101), or components of MetS at baseline and during the follow-up (n = 5,613). Because the amount of missing data varied for each component of MetS, to preserve statistical power as much as possible, we used all available data for individual component analyses. Thus, the sample size differed for each component of MetS incidence: n = 8,904 for central obesity, 8,500 for hypertriglyceridemia, 8,249 for reduced high-density lipoprotein (HDL) cholesterol, 6,696 for elevated blood pressure, 7,124 for impaired fasting glucose; and the sample size also differed for each component of MetS reversion: n = 4,111 for central obesity, 3,919 for hypertriglyceridemia, 3,578 for reduced HDL cholesterol, 4,429 for elevated blood pressure, and 4,138 for impaired fasting glucose. The final analysis sample consisted of 14,399 subjects (9,275 without MetS and 5,124 with MetS at baseline). Compared to the analytical sample, the excluded subjects were older, tended to be males, had longer sleep duration and midday napping, poorer sleep quality, and higher levels of waist circumference, triglycerides, systolic blood pressure, diastolic blood pressure, and fasting blood glucose (Table S1 in the supplemental material). The study was approved by the Ethics and Human Subject committee of Tongji Medical College, and Dongfeng General Hospital, DMC. All study participants provided informed consent.

Assessment of MetS

The MetS was defined using the consensus statement as the presence of three or more of the following[16]: (1) central obesity: waist circumference ≥ 90 cm in men or ≥ 80cm in women; (2) hypertriglyceridemia: triglycerides ≥ 1.7 mmol/L (drug treatment for elevated triglycerides is an alternate indicator); (3) reduced HDL cholesterol levels: HDL cholesterol < 1.0 mmol/L in men, or < 1.3 mmol/L in women (drug treatment for reduced HDL cholesterol is an alternate indicator); (4) elevated blood pressure: blood pressure ≥ 130/85 mmHg or current use of antihypertensive medications; or (5) impaired fasting glucose: fasting glucose ≥ 5.6 mmol/L or the use of diabetes medication.

Incidence of MetS was defined as not having MetS at baseline but having MetS after 5 y of follow-up, whereas reversion was defined as having MetS at baseline but not at the 5-y assessment.

Assessment of Sleep Duration and Midday Napping

Sleep duration was assessed by asking: "What time did you usually go to sleep at night and wake up in the morning over the previous 6 mo?" We categorized sleep duration into five groups: < 6 h, 6 to < 7 h, 7 to < 8 h, 8 to < 9 h, ≥ 9 h. Habit nap takers were defined as those who had taken a planned or regular nap as a habit more than three times per week after lunch over the past 6 mo. Midday napping was assessed by asking "Did you have a habit of taking midday nap over the previous 6 mo?" Those who responded 'yes' were further asked about the duration of their naps. Midday napping was thereby categorized as no napping (0 min), 1 to < 30 min, 30 to < 60 min, 60 to < 90 min, and ≥ 90 min. Additionally, we computed total sleep time by summing up nighttime sleep duration and midday napping, and we also categorized it into 5 groups: < 7.5 hours, 7.5 to < 8.5 hours, 8.5 to < 9.5 hours, 9.5 to < 10.5 hours, ≥ 10.5 h.

Assessment of Covariates

Semistructured questionnaires were used to collect information on demographics (age, sex, education, and marital status), diets, lifestyle habits such as smoking status (current, former, never), drinking status (current, former, never) and physical activity, occupational history, environmental exposures, and family and medical histories. Participants who were smoking at least one cigarette per day for more than half a year were considered as current smokers; those who were drinking at least one time per week for more than half a year were defined as current drinkers. Physical activity was defined as regular exercise more than 20 min per day over the past 6 mo.[17] Participants were also asked to report the average times spent per week and the average hours spent per time on physical activity. The duration of physical activity (hours per week) was calculated according to the following formula: frequency (times per week) × duration (hours per time). Dietary data were categorized as six major food groups: eggs, meat, fish, fruits, vegetables, and beans. Participants were asked about the frequency of habitual consumption during the previous 12 mo and selected among four categories of frequency (times per day, times per week, times per month, and times per year). The frequency was transformed into times per week in the subsequent analysis. Sleep quality was assessed by asking whether the individuals experienced any of the following three types of sleep problems: experiencing difficulties in falling asleep lasting for 30 min or longer, waking up frequently during the night, or waking up too early in the morning and being unable to get back to sleep.[18] Participants were asked to choose from three responses: never, one to two times per week, and three or more times per week, which corresponded to good, fair, and poor sleep quality, respectively. Standing height, body weight, and waist circumference were measured with subjects in light indoor clothing without shoes. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

Fasting blood in the morning was drawn before physical examinations using standardized procedures. Blood lipids [total cholesterol, triglycerides, HDL-cholesterol, and low-density lipoprotein (LDL) cholesterol], fasting glucose, hepatic function, renal function, a complete blood count, and tumor-associated antigens were measured specifically for the DFTJ cohort study at the hospital's laboratory.

Statistical Analysis

The distributions of the numerical data were assessed by the one-sample Kolmogorov-Smirnov test. The differences of baseline characteristics between groups according to MetS incidence and reversion status were evaluated by t-test for continuous variables and chi-square test for categorical variables. Multivariate logistic regression models were used to examine the associations of sleep duration and midday napping with incidence and reversion of MetS and of its components calculated with odds ratios (ORs) and 95% confidence interval (95% CI). We performed two separate analyses: the first on the incidence of MetS in participants who did not have the condition at baseline, and the second on reversion of MetS in participants who had the condition at baseline. We used 7 to < 8 h of nighttime sleep duration and 1 to < 30 min of midday napping as the reference groups based on published literature showing their beneficial effects for adults.[19,20] Potential confounders were adjusted including age, sex, BMI, education (primary school or below, middle school, high school or beyond), smoking status (never/former/current), drinking status (never/former/current), physical activity (hours per week), sleep quality (good/fair/poor), use of hypnotics (yes/no), and diet frequency (times per week, for eggs, meat, fish, fruits, vegetables, and beans). We further adjusted for midday napping for the sleep-MetS incidence or reversion relationships and nighttime sleep duration for the nap-MetS incidence or reversion relationships. All statistical analysis was performed using SAS version 9.3 (SAS institute Inc., Cary, NC) and the significance tests were two-tailed with P values below 0.05.

RESULTS

Table 1 shows the baseline characteristics of participants according to changes in the MetS status. The mean age of the study population at baseline was 62.5 ± 7.4 y, and the majority are females (56.5%). Among the 9,275 participants having no MetS at baseline, 2,447 (26.4%) occurred at follow-up, and among the 5,124 participants with MetS at baseline, 1,462 (28.5%) recovered by follow-up. Participants with MetS incidence were more likely to be female and overweight than those without MetS. In contrast, participants with MetS reversion tended to be male and of normal weight than those with MetS at baseline. As expected, the changes of all components contributing to MetS varied significantly by different MetS incidence and reversion status.

Table 2 lists the adjusted ORs for the incident risk of MetS and its individual components by categories of nighttime sleep duration. After adjustment for potential confounders, we found that longer nighttime sleep duration was significantly associated with an increased risk of incident MetS. Compared with the reference group of 7 to < 8 h per night, the adjusted

OR (95% CI) for MetS incidence was 1.29 (1.08–1.55) for sleeping ≥ 9 h per night, while other groups of sleep duration were not significantly related to MetS incidence. Analyses of the individual MetS components revealed that both shorter (< 6 h) and longer (≥ 9 h) nighttime sleep duration were associated with a greater risk of developing central obesity compared with sleep duration of 7 to < 8 h per night, and the ORs were 2.36 (95% CI, 1.32–4.23) and 1.28 (95% CI, 1.03–1.60), respectively; associations between other components and nighttime sleep duration categories were not significant.

As shown in Table 3, longer nighttime sleep duration ≥ 9 h was also associated with lower reversion of MetS. The OR (95% CI) for the 5-y MetS reversion in individuals with nighttime sleep duration ≥ 9 h compared with those of 7 to < 8 h was 0.80 (0.66–0.96). With respect to the components of MetS, longer sleepers (≥ 9 h) showed lower reversion of central obesity (OR, 0.73; 95% CI, 0.56–0.94) and hypertriglyceridemia (OR, 0.80; 95% CI, 0.66–0.96); while shorter sleepers (< 6 h) were less likely to revert reduced HDL cholesterol (OR, 0.54; 95% CI, 0.31–0.93).

Compared to subjects who napped for 1 to < 30 min, subjects with no napping and napping ≥ 90 min exhibited a 39% and 48% increased risk of MetS incidence, and the ORs were 1.39 (95% CI, 0.99–1.94) and 1.48 (95% CI, 1.05–2.10), respectively, whereas longer nap takers who napped ≥ 90 min had a 30% decreased risk of MetS reversion (OR, 0.70; 95% CI, 0.52–0.94), respectively (Table 4). No statistically significant associations were detected between midday napping and the 5-y incidence and reversion of all MetS components (Table S2 and Table S3 in the supplemental material).

Finally, we also examined the associations of total sleep time with incidence and reversion of MetS and its components in additional analyses. Compared with subjects reporting 7.5 to < 8.5 h of sleep per day, those with longer total sleep time (9.5 to < 10.5 h and ≥ 10.5 h) showed a higher incidence and a lower reversion of MetS, whereas those with longer total sleep time (≥ 10.5 h) exhibited a higher incidence and a lower reversion of central obesity (Table S4 and Table S5 in the supplemental material).

DISCUSSION

To the best of our knowledge, this is the first study to simultaneously study the relationships of sleep duration and midday nap with MetS incidence and reversion in middle-aged and older adults who have a high prevalence of MetS. Our findings indicated that the incidence of MetS was higher and the reversion of MetS was lower by longer sleep duration and midday napping.

Recently, Li et al. showed that both shorter (< 6 h) and longer (8–9 and ≥ 9 h) sleep duration were associated with a greater incidence of MetS in the general Chinese adult population aged 30–65 y.[14] Our results supported the longitudinal relationship of longer sleep duration and MetS incidence with the larger sample size. Moreover, we excluded chronic conditions (such as self-reported coronary heart disease, stroke, and cancer at baseline) from analyses to rule out residual confounding due to chronic conditions, and to examine whether there was a genuine link between sleep duration or midday napping and MetS

Table 1—Baseline characteristics and 5-y changes in metabolic syndrome components among the study population.

	MetS Incidence			MetS Reversion		
	No (n = 6,828)	Yes (n = 2,447)	P value [a]	No (n = 3,662)	Yes (n = 1,462)	P value [a]
Age (y)	62.0 (7.5)	62.1 (7.2)	0.296	63.4 (7.4)	63.1 (7.5)	0.247
Sex, female (%)	48.9	62.7	< 0.001	67.1	55.3	< 0.001
BMI (kg/m^2)	22.9 (2.8)	24.8 (2.8)	< 0.001	26.6 (3.1)	25.3 (2.9)	< 0.001
Smoking status (%)			< 0.001			0.002
Never	67.0	76.0		77.7	73.0	
Former	10.9	8.9		8.9	10.4	
Current	22.1	15.1		13.4	16.6	
Drinking status (%)			< 0.001			< 0.001
Never	69.3	75.0		78.2	72.2	
Former	4.8	3.4		4.1	5.1	
Current	25.9	21.6		17.7	22.7	
Physical activity, hours per week	8.0 (6.7)	7.7 (6.4)	0.091	7.6 (6.4)	7.8 (6.5)	0.381
Education (%)			0.001			< 0.001
Primary school or below	27.1	29.5		33.6	28.9	
Middle school	36.3	38.0		39.5	38.2	
High school or beyond	36.6	32.5		26.9	32.9	
Sleep quality (%)			0.311			0.978
Good	36.5	35.9		37.2	37.3	
Fair	53.1	54.6		52.9	52.6	
Poor	10.4	9.5		9.9	10.1	
Use of hypnotics (%)	2.5	2.0	0.174	3.1	2.5	0.310
Diet frequency, times per week						
Eggs	3.9 (3.2)	3.7 (3.1)	0.005	3.7 (3.1)	3.7 (3.1)	0.807
Meat	3.6 (3.7)	3.5 (3.7)	0.169	3.3 (3.6)	3.4 (3.7)	0.552
Fish	1.8 (2.5)	1.7 (2.2)	0.036	1.7 (2.3)	1.8 (2.3)	0.074
Fruits	5.2 (4.7)	5.3 (4.6)	0.943	5.4 (4.8)	5.2 (4.6)	0.259
Vegetables	14.0 (5.2)	14.1 (5.1)	0.553	14.0 (5.3)	14.1 (5.1)	0.593
Beans	3.5 (3.3)	3.4 (3.3)	0.650	3.4 (3.3)	3.5 (3.4)	0.214
Changes in MetS components						
Waist circumference, cm	1.3 (7.2)	4.7 (7.0)	< 0.001	1.1 (7.1)	−3.8 (8.5)	< 0.001
Triglycerides, mmol/L	0.06 (0.55)	0.47 (1.01)	< 0.001	0.04 (1.70)	−0.45 (1.11)	< 0.001
HDL cholesterol, mmol/L	0.11 (0.50)	−0.08 (0.49)	< 0.001	0.01 (0.49)	0.29 (0.48)	< 0.001
Systolic blood pressure, mmHg	12.2 (19.9)	19.2 (21.1)	< 0.001	14.4 (22.8)	6.2 (23.0)	< 0.001
Diastolic blood pressure, mmHg	2.8 (12.3)	5.1 (12.9)	< 0.001	1.8 (13.7)	−2.0 (13.1)	< 0.001
Fasting blood glucose, mmol/L	0.0 (1.1)	0.4 (1.6)	< 0.001	0.1 (2.0)	−0.4 (1.9)	< 0.001

Values are mean (standard deviation) or percentage. [a] t-test for continuous variables and chi-square test for categorical variables. BMI, body mass index; HDL, high-density lipoprotein; MetS, metabolic syndrome.

incidence. In addition, our findings are novel and strengthen evidence of the adverse effect of longer sleep duration on MetS reversion.

Regarding the components of MetS, the increased OR of central obesity associated with longer sleep duration is consistent with previously reported positive relations of longer sleep duration and adiposity.[9,21] Central obesity is the most prevalent manifestation of MetS, and a growing number of evidence suggests a close correlation of increased abdominal fat with MetS and other related metabolic abnormalities.[22,23] In long sleepers, the physical inactivity due to increased nighttime sleep may reduce energy expenditure, which may contribute to obesity and development of MetS.[24] In agreement with a previous study reporting an OR of 1.13 (95% CI, 1.02–1.24) for elevated triglycerides among individuals with prolonged sleep

duration,[9] we also found that longer nighttime sleep duration ($\geq$ 9 h) was significantly associated with lower reversion of hypertriglyceridemia. We then speculate that the effect of longer sleep duration on the incidence or reversion of MetS may be predominantly mediated through changes in abnormal fat distribution and dyslipidemia.

Shorter sleep duration (< 6 h) was not related to the incidence or reversion of MetS in the current study, which was in contrast with previous cohort reports.[11–13] Choi et al.[11] observed an association between shorter sleep duration (< 6 h) and MetS incidence among Korean females aged 40–55 y (n = 1,107). In another study of worksite males aged 35–63 y in Japan (n = 948), sleep deprivation was also related to an elevated risk of MetS incidence.[12] Moreover, shorter sleep duration (< 6 h) was also an independent risk factor for incident MetS among

Table 2—Odds ratio for the 5-y incidence of metabolic syndrome and its individual components by nighttime sleep duration.

Variable	Nighttime Sleep Duration, hours				
	< 6	6 to < 7	7 to < 8	8 to < 9	≥ 9
MetS (n = 9,275)					
N (yes/no)	43/124	161/455	703/2,015	996/2,808	544/1,426
Incidence rate (%)	25.75	26.14	25.86	26.18	27.61
Adjusted OR (95% CI)	1.11 (0.65–1.89)	1.08 (0.83–1.41)	Reference	1.10 (0.95–1.28)	1.29 (1.08–1.55)
Central obesity (n = 8,904)					
N (yes/no)	58/103	158/407	697/1,893	950/2,694	539/1,405
Incidence rate (%)	36.02	27.96	26.91	26.07	27.73
Adjusted OR (95% CI)	2.36 (1.32–4.23)	0.99 (0.72–1.37)	Reference	0.98 (0.81–1.18)	1.28 (1.03–1.60)
Hypertriglyceridemia (n = 8,500)					
N (yes/no)	23/127	96/475	365/2,146	515/2,954	289/1,510
Incidence rate (%)	15.33	16.81	14.85	16.06	15.15
Adjusted OR (95% CI)	0.99 (0.51–1.92)	1.16 (0.85–1.59)	Reference	1.00 (0.82–1.20)	1.20 (0.96–1.50)
Reduced HDL cholesterol (n = 8,249)					
N (yes/no)	21/127	65/499	315/2,112	407/2,963	232/1,508
Incidence rate (%)	14.19	11.52	12.98	12.08	13.33
Adjusted OR (95% CI)	1.21 (0.62–2.37)	0.88 (0.61–1.28)	Reference	0.91 (0.74–1.12)	1.23 (0.96–1.56)
Elevated blood pressure (n = 6,696)					
N (yes/no)	54/72	238/220	994/946	1,382/1,376	742/672
Incidence rate (%)	42.86	51.97	51.24	50.11	52.48
Adjusted OR (95% CI)	0.81 (0.48–1.37)	1.29 (0.97–1.71)	Reference	1.01 (0.86–1.19)	1.16 (0.96–1.41)
Impaired fasting glucose (n = 7,124)					
N (yes/no)	48/101	164/335	690/1,362	1,024/1,972	461/967
Incidence rate (%)	32.21	32.87	33.63	34.18	32.28
Adjusted OR (95% CI)	0.89 (0.51–1.55)	1.05 (0.80–1.38)	Reference	1.16 (0.99–1.36)	0.99 (0.82–1.20)

Adjusted for age, sex, body mass index, education, smoking status, drinking status, physical activity, midday napping (continuous), sleep quality, use of hypnotics, and diet frequency (times per week, for eggs, meat, fish, fruits, vegetables, and beans). CI, confidence interval; HDL, high-density lipoprotein; MetS, metabolic syndrome; OR, odds ratio.

2,579 adults aged about 55 y in Korea.[13] Our study consisted of retired employees who were generally older than those in the three former cohorts. Because of reduced participation in social or physical activities due to retirement, the elderly have more opportunities to go to bed earlier and sleep longer than younger adults. However, long sleep duration may not actually be long sleep as it could be long time in bed but with poor sleep quality. Self-reported sleep duration assessed by questionnaire did not allow us to differentiate time asleep from time in bed. The relatively small number of shorter sleepers (n = 251) may be one explanation for the absence of associations between shorter sleep duration and incidence or reversion of MetS. However, we observed that subjects who slept < 6 h per night exhibited higher incidence of central obesity and lower reversion of reduced HDL-cholesterol. Taheri et al.[25] previously showed that short sleep duration was significantly associated with reduced leptin and elevated ghrelin levels, which would increase appetite and lead to the development of obesity. The preliminary findings related to short sleep duration and incidence or reversion of MetS and its components should be confirmed in future studies.

Our results further revealed that prolonged midday napping was also associated with an increased risk of MetS incidence and reduced reversion of MetS. Midday napping is a common practice in China, especially among older adults, and a short nap is traditionally considered as a healthy habit.[26] However, conflicting results regarding the rationality of midday napping have been generated in epidemiologic studies. Some studies have reported that napping is associated with a higher risk for diabetes and all-causes mortality among older adults.[27,28] In line with previous cross-sectional studies showing a positive relationship of longer napping with a higher risk for MetS,[10,29] we found that excessive napping (≥ 90 min) was also an independent predictor of incident MetS and might exert an adverse effect on the MetS reversion. Nonetheless, the findings should be interpreted cautiously because we did not see any significant difference between napping categories and incidence or reversion of MetS components.

The potential mechanisms underlying these findings remain to be investigated. Longer sleep duration or napping could be related to disrupted circadian rhythms and/or hormonal alterations, which may predispose to insulin resistance, a key characteristic in MetS pathophysiology.[9,30,31] In addition, chronic inflammation, generation of reactive oxygen species, and sympathetic activation may also play a central role in the relationship between excessive sleep or napping and MetS.[32,33] Furthermore, it could be argued that longer sleep duration or midday napping may be a consequence of an underlying illness, and therefore the observed sleep/nap/MetS relationship may be caused by preexisting diseases.

Table 3—Odds ratios for the 5-y reversion of metabolic syndrome and its individual components by nighttime sleep duration.

Variables	< 6	6 to < 7	7 to < 8	8 to < 9	≥ 9
			Nighttime Sleep Duration, h		
MetS (n = 5,124)					
N (yes/no)	26/58	108/224	417/1,027	628/1,533	283/820
Reversion rate (%)	30.95	32.53	28.88	29.06	25.66
Adjusted OR (95% CI)	1.07 (0.64–1.78)	1.23 (0.94–1.60)	Reference	0.97 (0.83–1.13)	0.80 (0.66–0.96)
Central obesity (n = 4,111)					
N (yes/no)	15/54	54/220	231/920	358/1,397	155/707
Reversion rate (%)	21.74	19.71	20.07	20.40	17.98
Adjusted OR (95% CI)	0.99 (0.49–1.99)	1.00 (0.69–1.46)	Reference	0.89 (0.72–1.10)	0.73 (0.56–0.94)
Hypertriglyceridemia (n = 3,919)					
N (yes/no)	23/47	96/132	468/614	682/984	336/537
Reversion rate (%)	32.86	42.11	43.25	40.94	38.49
Adjusted OR (95% CI)	0.65 (0.38–1.10)	0.91 (0.67–1.23)	Reference	0.91 (0.77–1.07)	0.80 (0.66–0.96)
Reduced HDL cholesterol (n = 3,578)					
N (yes/no)	28/33	121/89	557/437	869/643	436/365
Reversion rate (%)	45.90	57.62	56.04	57.47	54.43
Adjusted OR (95% CI)	0.54 (0.31–0.93)	1.00 (0.73–1.36)	Reference	1.02 (0.86–1.20)	0.85 (0.70–1.04)
Elevated blood pressure (n = 4,429)					
N (yes/no)	9/63	16/263	90/1,165	134/1,738	63/888
Reversion rate (%)	12.50	5.73	7.17	7.16	6.62
Adjusted OR (95% CI)	1.72 (0.78–3.76)	0.72 (0.41–1.27)	Reference	0.97 (0.73–1.29)	0.89 (0.63–1.25)
Impaired fasting glucose (n = 4,138)					
N (yes/no)	13/52	68/190	246/931	347/1,369	192/730
Reversion rate (%)	20.00	26.36	20.90	20.22	20.82
Adjusted OR (95% CI)	1.00 (0.53–1.89)	1.41 (1.03–1.93)	Reference	0.94 (0.78–1.13)	1.01 (0.81–1.25)

Adjusted for age, sex, body mass index, education, smoking status, drinking status, physical activity, midday napping (continuous), sleep quality, use of hypnotics, and diet frequency (times per week, for eggs, meat, fish, fruits, vegetables, and beans). CI, confidence interval; HDL, high-density lipoprotein; MetS, metabolic syndrome; OR, odds ratio.

Table 4—Odds ratios for the 5-y incidence and reversion of metabolic syndrome by midday napping.

Variables	0	1 to < 30	30 to < 60	60 to < 90	≥ 90
			Midday Napping, min		
MetS incidence (n = 9,275)					
N (yes/no)	1,041/2,813	53/193	310/872	606/1,726	437/1,224
Incidence rate (%)	27.01	21.54	26.23	25.99	26.27
Adjusted OR (95% CI)	1.39 (0.99–1.94)	Reference	1.36 (0.96–1.94)	1.35 (0.96–1.89)	1.48 (1.05–2.10)
MetS reversion (n = 5,124)					
N (yes/no)	575/1,429	203/469	373/990	210/472	101/302
Reversion rate (%)	28.69	30.21	27.37	30.79	24.94
Adjusted OR (95% CI)	0.92 (0.76–1.13)	Reference	0.85 (0.69–1.05)	0.94 (0.74–1.20)	0.70 (0.52–0.94)

Adjusted for age, sex, body mass index, education, smoking status, drinking status, physical activity, nighttime sleep duration (continuous), sleep quality, use of hypnotics, and diet frequency (times per week, for eggs, meat, fish, fruits, vegetables, and beans). CI, confidence interval; MetS, metabolic syndrome; OR, odds ratio.

Limitations

Some limitations of the current study should be addressed. First, self-reported sleep duration and midday napping were used in our analyses and they could have been prone to misclassification. Second, the measurements of snoring, obstructive sleep apnea, or neck circumference were not available in the questionnaire and physical examination, so we were unable to further adjust for these factors. Third, information on physical activity was obtained from questionnaires. Self-reported physical activity is also a major confounder that may be affected by bias (social desirability and recall bias, particularly in older individuals). Finally, the study was performed in middle-aged and older Chinese adults, and thus the findings cannot be extrapolated to other age groups or ethnics.

In conclusion, our data suggest that longer sleep duration (≥ 9 h) and midday napping (≥ 90 min) are independently

associated with a higher risk of MetS incidence and lower reversion of MetS. The significant risks for incidence or reversion of certain components of MetS persist in shorter and longer sleep duration but diminish according to napping categories. Future prospective studies and randomized clinical trials using objective measures of sleep depth, continuity, and sleep disordered breathing are needed to corroborate these findings and to identify the biologic pathways by which sleep or nap affects the development or reversal of MetS.

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DISCLOSURE STATEMENT