ORIGINAL RESEARCH

# Relationship between sleep duration and clustering of metabolic syndrome diagnostic components

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**Objective:** To examine the relation between sleep duration and metabolic syndrome (MetS).

**Methods:** We examined the baseline data from 4356 healthy workers (3556 men and 800 women) aged 19–69 years. The physical activity of each participant was classified according to the International Physical Activity Questionnaire (IPAQ). We defined four components of MetS diagnostic components in this study as follows: 1) high blood pressure (BP) systolic BP [SBP] $\geq$ 130 mmHg, or diastolic BP [DBP] $\geq$ 85 mmHg, or on medication; 2) dyslipidemia (high-density lipoprotein-cholesterol concentration <40 mg/dL, or triglycerides concentration $\geq$150 mg/dL, or on medication; 3) impaired glucose tolerance (fasting blood sugar concentration $\geq$ 110 mg/dL, or if less than 8 hours after meals $\geq$ 140 mg/dL), or on medication; and 4) overweight (body mass index [BMI] $\geq$ 25 kg/m$^2$), or obesity (BMI $\geq$ 30 kg/m$^2$). There were 680 participants in the group, with sleep duration <6 hours (15.6%).

**Results:** Those who had 0–4 MetS diagnostic components, including overweight, accounted for 2159, 1222, 674, 255, and 46 participants, respectively, in the Poisson distribution. Poisson regression analysis revealed that independent factors that contributed to the number of MetS diagnostic components were being male (regression coefficient b = 0.752, $P < 0.001$), age (b = 0.026, $P < 0.001$), IPAQ classification (b = −0.238, $P = 0.034$), and alcohol intake (mL/day) (b = 0.018, $P < 0.001$). Short sleep duration (<6 hours) was also related to the number of MetS (b = 0.162, $P < 0.001$). The results of analyses with obesity component showed a similar association.

**Conclusion:** Short sleep duration was positively associated with the number of MetS diagnostic components independent of other lifestyle habits.

**Keywords:** short sleep duration, MetS diagnostic components, obesity

## Introduction

The components of metabolic syndrome (MetS) diagnostic criteria, including high blood pressure (BP), dyslipidemia, impaired glucose tolerance (IGT), and obesity are thought to be related to daily lifestyle habits, including alcohol drinking, smoking, and physical activity.[1–4] It has also been reported that both a decrease and an increase in sleep duration were associated with an increase in cardiovascular and noncardiovascular mortality.[5,6] U-shaped associations were observed between sleep (<5, 5, 6, 7, $\geq$8 hours) and MetS.[7]

Numerous studies have shown that separate components of MetS are associated with a higher risk of coronary heart disease and stroke, and that a rise in the number of MetS components increases the incidence of cardiovascular disease (CVD) events following myocardial infarction.[8–10] Thus, preventing development of each component of MetS

using diagnostic criteria is more important than dichotomizing people into two groups, with and without MetS.

In the present study we comprehensively examined cross-sectionally the relation between sleep duration and other lifestyle habits including physical activity, smoking, alcohol intake, and the number of MetS diagnostic components in a large sample of healthy workers in Japan.

## Methods

### Participants

We analyzed baseline data from the High-Risk and Population Strategy for Occupational Health Promotion (HIPOP-OHP) Study.[11–14] In brief, HIPOP-OHP was an interventional survey to establish a methodology for reducing CVD risk factors at the workplace. This study population consisted of full-time workers at 12 large-scale companies throughout Japan. Each company had 500–1000 employees. Researchers followed data on CVD risk factors, lifestyle habits and consciousness about health, based on nutrition, physical activity, and smoking for 4 years.[11–14] This study was performed as part of the management of safety and health with the approval of the Safety Hygiene Committee at each company. Accordingly, all employees were enrolled in this study. However, participation was voluntary, and we explained there was no need for participants to answer the required questionnaire if they did not want to. Approval for the study was obtained from the Institutional Review Board of Shiga University of Medical Science for ethical issues (No. 10–16). From 1999–2000, baseline data were collected from 7346 male and female workers aged from 19 to 69 years old.

The present study examined baseline data from 4356 participants (3556 men and 800 women) ages 19–69 years (mean ± standard deviation: $41.3 \pm 9.6$ years) who underwent physical examination, a lifestyle survey, and blood chemical examination.

### Data collection and standardization

Physical and laboratory data were standardized according to the manual of the HIPOP-OHP research group.[11] Briefly, after 5 minutes of silent rest measured by a sandglass, blood pressure was measured twice for each participant using an automatic sphygmomanometer (Nihon Colin, BP-103iII) at each company, and the mean value was recorded. To measure the lipid concentrations in each participant, the company established a contract with a clinical laboratory; the blood testing was standardized through the US Cholesterol Reference Method Laboratory Network (CRMLN).[15] The body mass index (BMI) was calculated as weight (kg) divided by height squared (m²).

Participants were asked about the type of, and time spent on, physical activities in their spare time for recreation, exercise, or sport in the previous month. The physical activity of each participant was converted into metabolic equivalent task (MET)-minutes per week (=MET level × minutes of activity/day × days per week) according to IPAQ,[16] and participants were classified into four classes of physical activity as: class 1, sedentary (<600 MET-minutes per week); class 2, some activity (<1500 but ≥600 MET-minutes per week); class 3, moderate activity (<3000 but ≥1500 MET-minutes per week); or class 4, high (≥3000 MET-minutes per week). Drinking habits for each subject were assessed by a questionnaire common to all companies.[12] The frequency of alcohol intake during a typical week and the total alcohol intake on each occasion were determined and used to calculate the alcohol intake per week. This value was then divided by 7 to obtain the average alcohol intake per day. Subjects were asked to estimate their alcohol intake based on gou, a traditional Japanese drinking unit corresponding to 23 g of ethanol. One gou is equivalent to 2 US and UK drink units, or 180 mL of sake, and its ethanol content is roughly equivalent to that of a bottle of beer (663 mL), two single shots of whiskey (70 mL), a half glass of shochu (110 mL), or 240 mL of wine. Drinkers were defined as those consuming more than 0.3 gou (0.6 drinks) per week (1 g of ethanol a day).

Sleep duration was investigated by the question, "How many hours of sleep do you get on an average weekday per night?" in the lifestyle survey. Sleep duration of participants was categorized in four groups: <6 hours, 6 to <7 hours, 7 to <8 hours, and ≥8 hours, with reference to a precedent study.[7]

We defined four components for MetS in this study according to previous studies[3,17,18] as follows: 1) high BP, SBP ≥ 130 mmHg, or DBP ≥ 85 mmHg, or the use of an anti-hypertensive drug; 2) dyslipidemia, either serum high-density lipoprotein (HDL) cholesterol concentration <40 mg/dL, or serum triglycerides (TG) concentration ≥150 mg/dL, or on medication for dyslipidemia; 3) IGT, fasting blood glucose concentration ≥ 110 mg/dL, or if less than 8 hours after meals ≥140 mg/dL), or on medication for diabetes mellitus; and 4) overweight, BMI ≥ 25 kg/m², or obesity, BMI ≥ 30 kg/m².

### Statistical analyses

The chi-square statistical test for nominal variables and one way analysis of variance for continuous variables were performed to assess whether there were significant differences among the groups stratified by sleep duration.

Associations between the number of MetS diagnostic components, including overweight component, and sleep duration categories, taking a sleep duration of 6–7 hours as a reference, were analyzed by Poisson regression models. Model 1 included sex and age as covariates. Model 2 included model 1 covariates + IPAQ classification, smoking (non-, past, or current smoker; nonsmoker serves as reference), alcohol intake (mL/day), and interaction terms (IPAQ × male, alcohol intake × male, current smoking × male). The above analyses were repeated after overweight component was replaced by obesity component. The associations between high BP, dyslipidemia, IGT, overweight, obesity, and sleep duration categories were analyzed by logistic regression models, adjusted for sex, age, IPAQ classification, smoking (non-, past, or current smoker; nonsmoker serves as reference), alcohol intake, and interaction terms (IPAQ × male, alcohol intake × male, current smoking × male) as covariates. All $P$ values were two-sided, and $P < 0.05$ was considered significant. All analyses were performed using SPSS v15 (Chicago, IL, USA).

## Results

Among the 4356 participants (3556 men and 800 women), 680 (15.6%) were in the group of sleep duration <6 hours, 1779 in the group of sleep duration 6 to <7 hours (40.8%), 1488 in the group of sleep duration 7 to <8 hours (34.2%), and 409 in the group of sleep duration >8 hours (9.4%). There were 974 overweight (BMI ≥ 25 kg/m$^2$) participants (22.4%), and 116 participants (2.7%) with obesity (BMI ≥ 30 kg/m$^2$). Those who had 0–4 MetS diagnostic components, including overweight component, accounted for 2159, 1222, 674, 255, and 46 persons, respectively, in the Poisson distribution. Characteristics of participants by group according to sleep duration are shown in Table 1. The mean SBP, DBP, alcohol intake, and percentage of current smokers were higher among the groups with a longer sleep duration. The mean BMI and percentage of obesity were lower among the groups with a longer sleep duration.

The results of Poisson regression analysis are shown in Table 2. The shortest sleep duration category contributed significantly to the number of MetS components in both models. Independent factors that contributed to the number of MetS diagnostic components were being male (regression coefficient b = 0.639, $P < 0.001$), age (b = 0.026, $P < 0.001$), <6 hours of sleep duration (b = 0.141, $P < 0.001$) in model 1. In model 2, factors significantly contributing to the number of MetS components

were being male (b = 0.752, $P < 0.001$), age (b = 0.026, $P < 0.001$), IPAQ classification (b = –0.238, $P = 0.034$), alcohol intake (mL/day) (b = 0.018, $P < 0.001$), and <6 hours of sleep duration (b = 0.162, $P < 0.001$). The interaction term (alcohol intake × male) contributed significantly to the number of MetS components (b = –0.017, $P < 0.001$). The contribution of current smoking (b = –0.115, $P = 0.559$) was not statistically significant. Although there were very few participants with obesity, the analyses repeated after overweight component was replaced by obesity component showed a similar association between short sleep duration and the number of MetS components.

The results of logistic regression analysis on associations between individual components of MetS and sleep duration adjusted for other lifestyle habits are shown in Table 3. For high BP, being male (odds ratio [OR] = 2.68, 95% confidence intervals = [1.58–4.52] $P < 0.001$), age (OR = 1.05 [1.04–1.06], $P < 0.001$), and IPAQ (OR = 0.65 [0.42–0.99], $P = 0.044$) contributed significantly. Sleep duration categories did not contribute to high BP. For dyslipidemia, being male (OR = 3.70 [2.02–6.74], $P < 0.001$), age (OR = 1.03 [1.02–1.03], $P < 0.001$), sleep <6 hours (OR = 1.27 [1.03–1.56], $P = 0.023$), and IPAQ (OR = 0.60 [0.37–0.98], $P = 0.040$) contributed significantly. For IGT, age (OR = 1.09 [1.08–1.12], $P < 0.001$), <6 hours sleep (OR = 1.49 [1.03–2.15], $P = 0.037$) contributed significantly. For overweight, being male (OR = 1.72 [1.01–2.95], $P < 0.001$), age (OR = 1.02 [1.01–1.02], $P = 0.048$), <6 hours sleep (OR = 1.31 [1.06–1.61], $P = 0.011$), and 7 to <8 hours of sleep duration (OR = 0.79 [0.66–0.94], $P = 0.010$) contributed significantly. For obesity, age (OR = 0.95 [0.93–0.97], $P < 0.001$), and <6 hours sleep (OR = 1.90 [1.18–3.05], $P = 0.008$) contributed significantly. Thus, for 3 out of 4 MetS diagnostic components, <6 hours sleep contributed positively. For overweight, 7 to <8 hours of sleep duration inversely contributed significantly.

## Discussion

In the present study, we found a significant positive association between short sleep duration (<6 hours compared with 6–7 hours sleep duration) and the number of MetS diagnostic components, regardless of BMI cutoff point was taken either ≥25 kg/m$^2$, or ≥30 kg/m$^2$. Most previous studies showed an association between short sleep duration and the risk of MetS, and some studies also showed that a longer sleep duration was associated with the risk of MetS. Santos et al studied 2164 Portuguese men and women, and found an association between a decrease in physical activity, an

**Table 1** Characteristics of participants by group according to sleep duration – HIPOP-OHP study

| | Sleep duration[a] | | | | Total | P value |
|---|---|---|---|---|---|---|
| | <6 hours | 6 to <7 hours | 7 to <8 hours | >8 hours | | |
| Person N | 680 | 1779 | 1488 | 409 | 4356 | |
| Age (years) | 40.4 ± 9.5 | 41.4 ± 9.4 | 41.4 ± 9.6 | 42.4 ± 10.0 | 41.3 ± 9.6 | 0.010 |
| Female (%) | 22.1 | 21.8 | 14.7 | 10.8 | 18.4 | <0.001 |
| SBP (mmHg) | 117 ± 17 | 117 ± 17 | 119 ± 17 | 121 ± 16 | 118 ± 17 | 0.003 |
| DBP (mmHg) | 72 ± 12 | 72 ± 12 | 73 ± 12 | 75 ± 12 | 73 ± 12 | <0.001 |
| High BP (%) | 24.3 | 24.1 | 25.8 | 28.4 | 25.1 | 0.275 |
| Dyslipidemia (%) | 29.6 | 25.9 | 26.3 | 28.4 | 26.8 | 0.251 |
| IGT (%) | 7.5 | 6.0 | 6.3 | 7.3 | 6.5 | 0.501 |
| BMI (kg/m$^2$) | 23.3 ± 3.5 | 23.0 ± 3.2 | 22.8 ± 3.0 | 22.8 ± 3.0 | 23.0 ± 3.2 | 0.004 |
| BMI ≥ 25 kg/m$^2$ (%) | 27.2 | 23.1 | 19.5 | 21.8 | 22.4 | <0.001 |
| BMI ≥ 30 kg/m$^2$ (%) | 4.7 | 2.5 | 2.3 | 1.5 | 2.7 | 0.003 |
| IPAQ | 1.3 ± 0.6 | 1.3 ± 0.6 | 1.4 ± 0.7 | 1.3 ± 0.7 | 1.3 ± 0.6 | 0.005 |
| Current smoking (%) | 42.9 | 44.9 | 47.8 | 57.5 | 46.7 | <0.001 |
| Alcohol intake (mL/day) | 17.9 ± 32.6 | 17.6 ± 27.9 | 20.9 ± 29.7 | 27.7 ± 39.9 | 19.7 ± 30.7 | <0.001 |
| MetS No A[b] | 0.88 ± 0.99 | 0.79 ± 0.97 | 0.78 ± 0.95 | 0.86 ± 1.00 | 0.81 ± 0.97 | 0.064 |
| MetS No B[c] | 0.66 ± 0.82 | 0.58 ± 0.79 | 0.61 ± 0.78 | 0.66 ± 0.82 | 0.61 ± 0.79 | 0.116 |

**Notes:** The chi-square statistical test for nominal variables and one way analysis of variance for continuous variables were performed to assess whether there were significant differences among the groups stratified by sleep duration. We defined four components for MetS in this study as follows: 1) High BP, SBP ≥ 130 mmHg, or DBP ≥ 85 mmHg, or the use of an antihypertensive drug; 2) dyslipidemia, HDL < 40 mg/dL, or TG ≥ 150 mg/dL, or on medication for dyslipidemia; 3) IGT, fasting blood sugar concentration ≥ 110 mg/dL, or if less than 8 hours after meals ≥ 140 mg/dL), or on medication for diabetes mellitus; 4) overweight, defined as BMI ≥ 25 kg/m$^2$, or obesity, defined as BMI ≥ 30 kg/m$^2$. [a]Sleep duration = average sleeping hours per night on weekdays. [b]MetS No A = number of MetS component including overweight component. [c]MetS No B = number of MetS component including obesity component.
**Abbreviations:** BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; IGT, impaired glucose tolerance; BMI, body mass index; IPAQ, International Physical Activity Questionnaire classification; MetS, metabolic syndrome; HDL, high-density lipoprotein; TG, triglycerides; IGT, impaired glucose tolerance.

increase in sleeping hours, and the risk of MetS.[19] Hall et al studied self-reported sleep duration associated with MetS in a cross-sectional community-based cohort and found that both short (<7 hours per night) and long (≥8 hours per night) sleep duration were significantly correlated with MetS in middle-aged adults.[7] On the other hand, in a study by Choi et al with 4222 Korean participants, short and long sleep duration were related to increased risk of MetS, while subjects with sleep duration of 7 hours demonstrated the lowest prevalence of MetS.[20]

Because obesity results in development of MetS diagnostic components, the most likely reason for the association

**Table 2** Independent factors that contributed to the number of metabolic syndrome diagnostic components and sleep duration and lifestyle habits – results of Poisson regression analysis

| Variable | Overweight | | | | Obesity | | | |
|---|---|---|---|---|---|---|---|---|
| | Model 1[a] | | Model 2[b] | | Model 1[a] | | Model 2[b] | |
| | β[c] | P value | β[c] | P value | β[c] | P value | β[c] | P value |
| Male gender | 0.639 | <0.001 | 0.752 | <0.001 | 0.670 | <0.001 | −0.154 | 0.805 |
| Age (year) | 0.026 | <0.001 | 0.026 | <0.001 | 0.028 | <0.001 | −0.049 | <0.001 |
| Sleep group <6 hours (680) | 0.141 | <0.001 | 0.162 | <0.001 | 0.152 | 0.007 | 0.641 | 0.008 |
| 6 to <7 hours (1779) | Ref | | Ref | | Ref | | Ref | |
| 7 to <8 hours (1488) | −0.057 | 0.152 | −0.045 | 0.270 | −0.007 | 0.878 | −0.032 | 0.893 |
| ≥8 hours (409) | −0.006 | 0.920 | −0.050 | 0.435 | 0.020 | 0.769 | −0.328 | 0.460 |
| IPAQ | | | −0.238 | 0.034 | | | −0.351 | 0.547 |
| Current smoking | | | −0.115 | 0.559 | | | −0.588 | 0.459 |
| Alcohol intake (mL/day) | | | 0.018 | <0.001 | | | 0.041 | 0.307 |
| IPAQ × male | | | 0.176 | 0.078 | | | 0.119 | 0.804 |
| Alcohol intake × male | | | −0.017 | <0.001 | | | −0.045 | 0.258 |
| Smoking × male | | | 0.158 | 0.382 | | | 0.271 | 0.689 |

**Notes:** Results of analysis by Poisson regression models on associations between the number of MetS diagnostic components (including overweight or obesity component) and lifestyle are shown. [a]Model 1, adjusted for sex and age. [b]Model 2, adjusted for the variables in model 1 plus IPAQ, current smoking, alcohol intake, and interaction terms (IPAQ × male, alcohol intake × male, current smoking × male). [c]β = regression coefficient.
**Abbreviations:** IPAQ, International Physical Activity Questionnaire classification; MetS, metabolic syndrome.

**Table 3** Independent factors that contributed to high BP, dyslipidemia, IGT, overweight, obesity and sleep duration including other lifestyle habits – results of logistic regression analysis

| Variable | High BP (N = 1094) | | Dyslipidemia (N = 1169) | | IGT (N = 282) | | Overweight (N = 974) | | Obesity (N = 116) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Male gender | 2.68[a] | 1.58–4.52 | 3.70[a] | 2.02–6.74 | 1.96 | 0.39–9.77 | 1.72[a] | 1.01–2.95 | 0.86 | 0.25–2.92 |
| Age | 1.05[a] | 1.04–1.06 | 1.03[a] | 1.02–1.03 | 1.09[a] | 1.08–1.12 | 1.02[b] | 1.01–1.02 | 0.95[a] | 0.93–0.97 |
| Sleep <6 hours (594) | 1.09 | 0.88–1.36 | 1.27[b] | 1.03–1.56 | 1.49[b] | 1.03–2.15 | 1.31[b] | 1.06–1.61 | 1.90[a] | 1.18–3.05 |
| 6 to <7 hours (1557) | Ref | | Ref | | Ref | | Ref | | Ref | |
| 7 to <8 hours (1297) | 1.06 | 0.90–1.26 | 0.96 | 0.82–1.14 | 1.01 | 0.74–1.37 | 0.79[b] | 0.66–0.94 | 0.97 | 0.61–1.54 |
| ≥8 hours (344) | 1.01 | 0.76–1.31 | 0.97 | 0.75–1.25 | 0.95 | 0.59–1.50 | 0.83 | 0.63–1.09 | 0.72 | 0.30–1.72 |
| IPAQ | 0.65[b] | 0.42–0.99 | 0.60[b] | 0.37–0.98 | 1.76 | 0.45–6.91 | 0.89 | 0.58–1.37 | 0.70 | 0.23–2.21 |
| Current smoking | 0.64 | 0.30–1.39 | 1.22 | 0.54–2.73 | 1.02 | 0.12–8.95 | 0.82 | 0.39–1.72 | 0.56 | 0.12–2.63 |
| Alcohol intake | 1.02 | 0.99–1.04 | 1.02 | 0.99–1.05 | 1.04 | 0.95–1.14 | 1.03 | 1.00–1.05 | 1.04 | 0.96–1.13 |
| IPAQ × male | 1.41 | 0.98–2.03 | 1.34 | 0.86–2.05 | 0.60 | 0.16–2.25 | 1.14 | 0.78–1.67 | 1.12 | 0.44–2.87 |
| Alcohol × male | 0.99 | 0.97–1.01 | 0.98 | 0.95–1.01 | 0.96 | 0.88–1.05 | 0.97[b] | 0.95–0.99 | 0.96 | 0.88–1.03 |
| Smoking × male | 1.35 | 0.67–2.70 | 1.06 | 0.50–2.22 | 0.98 | 0.12–7.92 | 1.29 | 0.67–2.51 | 1.31 | 0.35–4.93 |

**Notes:** ORs and 95% CIs of analyses by logistic regression models on associations between high BP, dyslipidemia, IGT, overweight (BMI ≥ 25 kg/m²), obesity (BMI ≥ 30 kg/m²) and sleep duration including other lifestyle habits and interaction terms (IPAQ × male, alcohol intake × male, current smoking × male) are shown. All covariates included are shown in this Table. [a]P < 0.01 [b]P < 0.05.
**Abbreviations:** OR, odds ratio; CI, confidence interval; BP, blood pressure; IGT, impaired glucose tolerance; BMI, body mass index; IPAQ, International Physical Activity Questionnaire classification.

between short sleep duration and MetS may come from the association between short sleep duration and obesity. We also found significant positive associations between sleep duration <6 hours and obesity. Furthermore, sleep duration 7–8 hours was associated with the lowest risk of obesity in our study. Previous studies indicated a clear association between short sleep duration and elevated BMI and obesity,[21–23] reduced leptin, and elevated ghrelin.[24,25] One mechanism by which short duration sleep may predispose to weight gain is by increasing caloric intake. Partial sleep deprivation experiments in humans caused hyperphagia. Comparing 4 hours of sleep per night to 10 hours over a period of 2 days, both hunger and appetite scores on a visual analog scale were elevated by sleep deprivation.[25] In a situation where food is readily available, sleep deprivation may simply represent an increased opportunity to eat, especially if most of the waking-time is spent in sedentary activities such as watching television.[26] In the epidemiologic literature, those studies that attempted to quantify caloric intake found no relationship between sleep duration and dietary consumption.[27–30] However, two epidemiologic studies demonstrated that short sleepers have reduced levels of leptin and elevated levels of ghrelin, supporting an effect of short sleep durations on appetite regulation.[24,31] Chronic partial sleep deprivation also clearly leads to feelings of fatigue, and this tiredness may lead to reductions in physical activity. In the Nurses' Health Study and Nurses' Health

Study 2, short sleep durations were associated with reduced reported physical activity.[27,32]

In the present study, short sleep duration was associated with the risk of IGT. Previous cross-sectional studies indicated that short and long sleep duration were associated with an increased risk of developing IGT or diabetes mellitus, independent of confounding factors.[33–35]

We also found an association between dyslipidemia and shorter sleep duration, and several studies have shown this association. In a study by van den Berg et al, people who slept longer and spent more time in bed had a higher total/HDL cholesterol ratio among 768 participants of the Rotterdam Study.[36] In another study by Kaneita et al, both short and long sleep duration were associated with a high serum TG level or a low HDL cholesterol level, whereas compared with men sleeping 6–7 hours, the risk of a high low-density lipoprotein (LDL) cholesterol level was lower among men with sleeping duration ≥8 hours.[37]

We found no association between high BP and sleep duration. Additional analysis between short duration sleep and hypertension (defined as SBP ≥ 140, or DBP ≥ 90 mmHg, or on anti-hypertensive medication) yielded similar results (data not shown). However, several studies showed an association between short sleep duration and hypertension. In a study in a cohort of 10,308 British civil servants aged 35–55 years, short sleep duration (≤5 hours per night) was associated with a higher risk of hypertension compared with a group sleeping

7 hours among women (but no association detected in men).[38] Gangwisch et al studied 4810 participants, and found that sleep duration of ≤5 hours per night was associated with a significantly increased risk of hypertension.[39] We have no possible explanations for the lack of association between high BP and short sleep duration in our study.

The strengths of our study include being population-based, large-scale, and multi-site, with highly standardized methods. Since the study included men and women of a broad range of ages, the findings are likely to be generalizable to middle-aged Japanese. However, our study has some limitations. First, this study was limited by its cross-sectional design. Thus, the causal implications of short sleep duration for MetS should be taken cautiously. Second, we did not measure waist circumference (WC). However, we showed in a population-based study that BMI and WC correlated very well in men and women, and that BMI could be used instead of WC in a study when the latter was not available.[40] Third, although we did not have data on food intake and sleep apnea, these may make important contributions to MetS.

In conclusion, our results indicated that shorter sleep duration (<6 hours of sleep duration per night) was associated with an increased number of MetS diagnostic components, and 7 to <8 hours of sleep duration was associated with the lowest risk of obesity.

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## Disclosure

None of the authors have any conflicts of interest related to this manuscript.

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