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Original Article

Short sleep duration, shift work, and actual days taken off work are predictive life-style risk factors for new-onset metabolic syndrome: a seven-year cohort study of 40,000 male workers

Osamu Itani [a], Yoshitaka Kaneita [b,*], Mikiko Tokiya [a], Maki Jike [b], Atsushi Murata [b], Sachi Nakagome [b], Yuichiro Otsuka [b], Takashi Ohida [b]

[a] Department of Public Health and Epidemiology, Faculty of Medicine, Oita University, Oita, Japan
[b] Division of Public Health, Department of Social Medicine, Nihon University School of Medicine, Tokyo, Japan

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ABSTRACT

Background: This longitudinal study investigated the effects of various lifestyle-related factors – including sleep duration, shift work, and actual days taken off work – on new-onset metabolic syndrome (MetS).

Methods and results: A total of 39,182 male employees (mean age 42.4 ± 9.8 years) of a local government organization in Japan were followed up for a maximum of seven years, between 1999 and 2006. Multivariate analysis (Cox proportional hazard method) identified seven high-risk lifestyle factors that were significantly associated with new-onset MetS or a range of metabolic factors (obesity, hypertension, hyperglycemia, dyslipidemia): (1) short sleep duration (<5 h/day), (2) shift work, (3) insufficient number of days off work, (4) always eating until satiety, (5) not trying to take every opportunity to walk, (6) alcohol intake ≥60 g/day, and (7) smoking. In addition, a higher number of these high-risk lifestyle factors significantly promoted the onset of MetS. The hazard ratio for MetS associated with 0–1 high-risk lifestyle parameters per subject at the baseline was set at 1.00. Hazard ratios associated with the following numbers of high-risk lifestyle parameters were: 1.22 (95% CI 1.15–1.29) for 2–3 of these parameters; and 1.43 (1.33–1.54) for 4–7.

Conclusion: An increase in the number of high-risk lifestyle factors – such as short sleep duration, shift work, and an insufficient number of days off work – increased the risk of MetS onset. Comprehensive strategies to improve a range of lifestyle factors for workers, such as sleep duration and days off work, could reduce the risk of MetS onset.

1. Introduction

According to the World Health Organization (WHO), fatalities resulting from non-communicable diseases (NCDs) accounted for 36 million (63.2%) of 57 million deaths from all causes, occurring worldwide in 2008 [1]. The fatalities according to disease were as follows: 17.3 million from cardiovascular diseases, 7.6 million from cancer, 4.2 million from chronic respiratory disease, and 1.3 million from diabetes mellitus [1]. The total direct medical costs for treating these four diseases were estimated to be 2.88 trillion dollars in 2010 [1]. NCDs are currently the leading cause of death in several countries, impoverishing individuals and families but also limiting the social and economic development of countries. The United Nations and WHO have issued warnings that NCDs and their socioeconomic effects are the largest health problem of the 21st century; however, it is anticipated that implementation of national-level comprehensive action plans would decrease NCD-related morbidity and adverse socioeconomic effects [1,2].

In Japan, the National Health Promotion Movement for the 21st Century has been strongly promoted as a national project to combat NCDs since 2002 [3]. Implementation of Specific Health Checkups and Specific Health Guidance [4], focusing specifically on metabolic syndrome (MetS), was endorsed for this project [3]. MetS is a cluster of different diseases affecting a single individual, including abdominal obesity, insulin resistance, dyslipidemia, and

* Corresponding author. Division of Public Health, Department of Social Medicine, Nihon University School of Medicine, 30-1 Ohyaguchikami-machi, Itabashi-ku, Tokyo 173-8610, Japan. Fax: +81 3 3972 5878.
E-mail address: nusmpublichealth@gmail.com (Y. Kaneita).

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elevated blood pressure, and is known to significantly increase the risk of cardiovascular disease and type 2 diabetes mellitus [5]. MetS is currently attracting attention as an important target in strategies for the prevention of arteriosclerotic diseases.

Improvement of lifestyle is regarded as the most important prevention strategy against MetS [6]. Previous studies have identified a range of lifestyle factors that pose a high risk for MetS onset, including exercise [7], diet [8], alcohol intake [9,10], and smoking [11]. More recently, further risk factors have been identified, such as short sleep duration and insufficient days off work [12]. Itani et al. reported that insufficient days off work per week was a risk factor for new-onset MetS in a cohort study involving approximately 30,000 male public servants who worked for local governments in Japan [13]. However, these studies had considerable limitations. First, no causal association could be determined, due to the cross-sectional design of the studies [12]. Second, the diagnosis of MetS may have been potentially inaccurate, due to insufficient data on the treatment of the individual diseases constituting MetS [13]. In addition, evaluation of the cumulative incidence over time was insufficient because the data collected during the observation period were not included in data analysis [13].

A longitudinal epidemiological study was planned to examine the association between MetS and lifestyle factors, avoiding the above-mentioned limitations. The present study met the following criteria: (1) identification of multiple individual risk factors for MetS onset among the key lifestyle-related parameters affecting workers, including sleep, work conditions (shift work), and days off; (2) a sample size of several tens of thousands of subjects; (3) a longitudinal study design; (4) inclusion of all data obtained during the observation period in the analysis; and (5) use of a database including treatment of individual diseases constituting MetS. Furthermore, a novel parameter was assessed: the effects of an increase in the number of high-risk lifestyle parameters on the onset of MetS, or the individual diseases constituting MetS. The effects of individual lifestyle factors on MetS onset have been investigated in previous epidemiological studies. To date, however, limited research on the effects of an increase in the number of lifestyle-related factors, including sleep and days off work, on MetS onset has been conducted in Japan and worldwide. The present study included sleep, shift work, and days off work as lifestyle-related factors for analysis. This resulted in a comprehensive analysis of the key lifestyle parameters affecting workers. It was considered that identifying the effects of an increase in the number of lifestyle habits on the onset of MetS might contribute to the development of recommendations for prevention of MetS.

2. Methods

2.1. Study subjects and data collection

This cohort study retrospectively analyzed the medical checkup data for employees of a local government organization in Japan. Medical checkups of all employees were conducted annually, and the data included in this study were from medical checkups between 1999 and 2006. The number of female employees (3286) was markedly smaller than that of male employees (42,136), and the types of work and work environment for males and females were substantially different in this organization. The study therefore excluded data for female employees from analyses, in order to ensure sample homogeneity. A total of 39,182 male employees underwent medical checkups in 1999 (consultation rate: 93.0%) and were followed up for a maximum of 7 years between 1999 and 2006. Most employees reaching the mandatory retirement age (60 years of age in this organization) retired, and were precluded from further annual medical checkups. Therefore, these employees were treated as dropouts. Finally, a total of 22,423 male employees receiving annual medical checkups between 1999 and 2006 were included in this study (complete follow-up rate: 57.2%).

2.2. Study variables and measurements

The checkups included the following: (1) body height/weight, blood pressure measurement; (2) blood test; (3) urinalysis; (4) a self-administered questionnaire; (5) electrocardiography; and (6) chest X-ray. Physical assessments included measurements of height, body weight, and blood pressure (systolic/diastolic). Blood pressure was measured twice in the right upper arm with the subject seated on a chair, using the auscultatory method.

As a condition of blood collection, the subjects were instructed not to take any food or beverage, except for water and tea, within 10 h before the checkup. The parameters included in the blood test were high-density lipoprotein (HDL) cholesterol, triglyceride, and fasting plasma glucose.

The questionnaire sought information on previous or present diseases (including current medication and outpatient care), physical and mental complaints, sleep duration, actual availability of weekly rest days, presence/absence of shift work, eating habits, exercise, alcohol consumption, and smoking. With regard to sleep hours, the subjects were requested to select their sleep hours per day as <5 h, ≥5 h but <7 h, or ≥7 h. The work regime followed in this organization was either fixed daytime work or shift work; the shift work cycles were: (1) a night shift every 3 days, (2) a night shift every 4 days, (3) a night shift every 5 days, (4) a night shift every 6 days, and (5) a night shift every 8 days. In this study, all five of these patterns were classified as “shift work”. The organization for which the subjects worked stipulated that 1 or 2 rest days per week were periodically provided in principle. It was also asked whether the subjects had been able to take weekly rest days over the past 1–2 months, with the following answer options: “able to take most of the available weekly rest days off” and “unable to often take weekly rest days off”.

Regarding eating habits, subjects were asked whether they ate in moderation, and were requested to select one of the following answers: always, sometimes, or never. Regarding exercise habits, subjects were asked whether they tried to take every opportunity to walk, for instance, by using the stairs, where possible. A two-point scale (yes or no) was used for the evaluation of exercise habits.

With regard to drinking habits, the subjects answered a question on whether they consumed alcoholic beverages. Subjects were asked to report their alcohol consumption per drinking session on a Japanese sake (rice wine)-converted basis. The pure alcohol intake was then calculated on the basis that the pure alcohol content per 180 mL of Japanese sake corresponds to 20 g. With regard to smoking habits, the subjects answered a question on whether they smoked, by selecting an option from among “yes”, “no”, and “quit smoking”. Smokers were asked to report the number of cigarettes smoked per day. With regard to mental complaints, the subjects answered questions such as whether they experienced irritability, reduced concentration, and lethargy.

2.3. Definitions of various metabolic diseases

2.3.1. Obesity

Obesity was defined as a body mass index (BMI) of ≥25 kg/m^2 according to the standards of the Japan Society for the Study of Obesity [14].

2.3.2. Hypertension

Hypertension was defined as a mean value of two systolic blood pressure measurements of ≥140 mmHg or a mean value of two diastolic blood pressure measurements of ≥90 mmHg, in accordance with criteria determined by WHO [15] and the Japanese Society of Hypertension [16]. Patients prescribed antihypertensive medication were also defined as hypertensive.

2.3.3. Hyperglycemia

Furthermore, in accordance with the criteria stipulated by the Japan Diabetes Society [17], a fasting plasma glucose level of ≥126 mg/dL was considered to represent hyperglycemia. Patients prescribed hypoglycemic medication were also defined as hyperglycemic.

2.3.4. Dyslipidemia

In accordance with the criteria stipulated by the Japan Atherosclerosis Society [18], a serum triglyceride level of ≥150 mg/dL was considered to be high, and an HDL cholesterol level of <40 mg/dL was defined as low. Patients prescribed antilipidemic medication were also defined as dyslipidemia.

2.4. Definition of metabolic syndrome

The definition of MetS in this study was adapted from the diagnostic criteria set by the Japanese Committee to Evaluate Diagnostic Standards for Metabolic Syndrome [19]. Specifically, the present study replaced the endpoint of visceral fat accumulation from the abdominal circumference criteria in the original criteria with the BMI criteria. The diagnostic criteria for MetS used in the present study were as follows: BMI ≥25 kg/m^2 and two or more of the following conditions being met: (1) systolic blood pressure measurements of ≥130 mmHg, or diastolic blood pressure measurements of 85 mmHg, or use of antihypertensive medication; (2) triglyceride ≥150 mg/dL, or HDL cholesterol <40 mg/dL, or use of antilipidemic medication; and (3) glucose ≥110 mg/dL, or use of hypoglycemic medication.

2.5. Definition of clustering of lifestyle factors

The following seven lifestyle-related parameters were defined as conferring a significantly high risk for new-onset obesity, hypertension, hyperglycemia, dyslipidemia, or MetS: (1) <5 h/day of sleep; (2) shift work; (3) insufficient days off work; (4) always eating until satiety; (5) not attempting to take every opportunity to walk; (6) consuming ≥60 g/day of pure alcohol (≥540 mL of Japanese sake); and (7) smoking.

2.6. Statistical analyses

The prevalence of obesity, hypertension, hyperglycemia, dyslipidemia, and MetS was calculated by age class (<30, 30–39, 40–49, >50 years) at the baseline (1999). A Mantel–Haenszel test for trend was performed to examine the age-class-based trends in the prevalence of each disease. The level of significance was set at $p < 0.05$.

After selecting subjects who were obese at the baseline, the Cox proportional hazards model (forced entry method) was applied, using new-onset obesity during the observation period as the endpoint. The following seven lifestyle-related parameters were used as explanatory variables in this test: sleep duration (≥5/<5 h/day); shift work (no/yes); actual use of weekly rest days (most rest days taken/most rest days not taken); eating in moderation (always/sometimes/never); trying to take every opportunity to walk (yes/no); alcohol intake (no current drinking habit/<60/≥60 g/day pure alcohol intake); smoking (non-smoker or quit smoking/<40/≥40 cigarettes/day). The analysis was adjusted for the following factors: age class; hypertension; hyperglycemia; dyslipidemia; and mental health complaints (irritability, reduced concentration, and lethargy). Subjects who did not undergo a medical checkup during the observation period were withdrawn from follow-up at that point. For hypertension, hyperglycemia, dyslipidemia, and MetS, the tests were performed in the same way as for obesity.

Finally, any lifestyle-related parameters found to be significantly associated with new onset of any of the following diseases was defined as high-risk: obesity, hypertension, hyperglycemia, dyslipidemia, or MetS. The Cox proportional hazards model was then applied, using the onset of each of the above-mentioned diseases as the objective variable, and the number of high-risk lifestyle parameters present at the baseline as the explanatory variable. The model was adjusted for the following variables: age class, hypertension, hyperglycemia, dyslipidemia, and mental health complaints. Subjects who did not undergo a medical checkup during the observation period were withdrawn from follow-up at that point. For hypertension, hyperglycemia, dyslipidemia, and MetS, the tests were performed in the same way as for obesity. All analyses were performed using SPSS 22 for Windows (IBM Corp, Armonk, NY, USA).

2.7. Ethical considerations

For the present study, the following measures were exercised to safeguard the privacy of the subjects: (1) only one researcher had access to the personal data of the subjects, and (2) the files containing the subjects' personal data were managed separately from those used for statistical analyses. This study was conducted in accordance with the tenets of the Personal Information Protection Act enforced in Japan and the Ethical Guidelines for Epidemiological Studies jointly announced by the Ministry of Health, Labor and Welfare and the Ministry of Education, Culture, Sports, Science and Technology of Japan.

3. Results

The characteristics of the subjects at the baseline (1999) are shown in Table 1. They ranged in age from 18 to 65 years (mean ± standard deviation (SD), 42.4 ± 9.8 years). Overall, 44.6% of the subjects worked shifts.

The prevalence of obesity, hypertension, hyperglycemia, dyslipidemia, and MetS by age class at the baseline (1999) are shown in Table S1. The prevalence (95% CI) of obesity, hypertension, hyperglycemia, dyslipidemia, and MetS were 44.7% (44.2–45.2%), 20.6% (20.2–21.0%), 7.9% (7.6–8.2%), 40.7% (40.2–41.2%), and 16.9% (16.5–17.3%), respectively. The Mantel–Haenszel test for trend indicated that the prevalence of each disease increased with age, and this correlation was statistically significant (all $p < 0.001$).

The associations between lifestyle-related parameters (sleep duration, shift work, actual use of weekly rest days, eating habits (eating in moderation), exercise habits (trying to take every opportunity to walk), alcohol intake, and smoking) at the baseline and new-onset obesity, hypertension, hyperglycemia, dyslipidemia, and MetS, during the seven-year follow-up period are shown in Table 2. The associations between the following lifestyle-related parameters and diseases were significant: sleep duration and new-onset obesity, hypertension, and MetS (all $p < 0.001$); shift work and new-onset hypertension ($p = 0.018$), dyslipidemia ($p = 0.034$), and MetS ($p = 0.029$); actual use of weekly rest days and new-onset obesity ($p = 0.039$), dyslipidemia ($p = 0.016$), and MetS ($p = 0.001$); eating in moderation and new-onset obesity ($p < 0.001$), hypertension ($p = 0.040$), dyslipidemia ($p = 0.051$), and MetS ($p < 0.001$); trying to take every opportunity to walk and new-onset hypertension ($p = 0.020$) and MetS ($p = 0.010$); alcohol intake and new-onset obesity ($p = 0.026$), hypertension ($p < 0.001$),

Table 1
Baseline characteristics of the study population.

	n	%
Age, years		
18–19	32	0.1
20–29	5572	14.2
30–39	8886	22.7
40–49	13,786	35.2
50–59	10,692	27.3
60–65	214	0.5
Sleep duration, hours/day		
<5	15,518	38.5
≥5 and <7	24,478	60.8
≥7	269	0.7
Shift work		
Day work only	16,835	45.4
A night shift every 3 days	889	2.4
A night shift every 4 days	14,504	39.1
A night shift every 5 days	2507	6.8
A night shift every 6 days	2236	6.0
A night shift every 8 days	43	0.1
Others	78	0.2
Actual use of weekly rest days		
Most taken	32,390	83.5
Most not taken	6396	16.5
Eating in moderation		
Always	23,084	59.0
Sometimes	11,216	28.7
Never	4834	12.4
Taking every opportunity to walk		
Yes	25,659	65.6
No	13,438	34.4
Drinking habits		
No drinking	6800	17.4
Intake of pure alcohol <40 g/day	14,463	37.0
Intake of pure alcohol 40–60 g/day	11,315	29.0
Intake of pure alcohol 60–100 g/day	5707	14.6
Intake of pure alcohol ≥100 g/day	773	2.0
Smoking habits		
No or quit smoking	16,609	42.5
Number of cigarettes smoked <20/day	4138	10.6
Number of cigarettes smoked ≥20/day and <40/day	15,480	39.6
Number of cigarettes smoked ≥40/day and <60/day	2675	6.8
Number of cigarettes smoked ≥60/day	204	0.5
Mental complaints		
Irritability		
No	37,876	96.7
Yes	1306	3.3
Reduced concentration		
No	38,710	98.8
Yes	472	1.2
Lethargy		
No	38,452	98.1
Yes	730	1.9

Of 39,182 male employees who underwent a medical checkup at the baseline (1999), those with missing data were excluded before the calculation was performed.

dyslipidemia ($p = 0.009$), and MetS ($p < 0.001$); and smoking and new-onset obesity ($p = 0.010$), hypertension ($p = 0.002$), hyperglycemia ($p < 0.001$), and dyslipidemia ($p < 0.001$).

The associations between the number of high-risk lifestyle parameters present at baseline and new-onset obesity, hypertension, hyperglycemia, dyslipidemia, and MetS during the observation period are shown in Table 3. Obesity ($p = 0.002$), hyperglycemia ($p < 0.001$), dyslipidemia ($p < 0.001$), and MetS ($p < 0.001$) were significantly associated with the number of high-risk lifestyle parameters present at baseline. The hazard ratio for first onset of MetS associated with 0–1 high-risk lifestyle parameters per subject at the baseline was set at 1.00. The hazard ratios associated with the following numbers of high-risk lifestyle parameters were: 1.22 (95% CI 1.15–1.29) for 2–3 of these parameters; 1.43 (1.33–1.54) for 4–7. It was noteworthy that an increase in the number of high-risk lifestyle parameters was associated with an increase in the hazard ratio (Table 3 and Fig. 1).

4. Discussion

The present longitudinal epidemiological study identified the high-risk lifestyle parameters associated with new-onset MetS, and examined the effect of the number of such parameters on the onset of MetS. This study had several advantages over previous investigations. First, it was a longitudinal study that included a sufficiently large sample of subjects, in the order of several tens of thousands. This ensured high epidemiological reliability and allowed conclusions to be drawn about causal associations between variables. Furthermore, the quality of the research was high, as the sampled population consisted of employees of a single organization, thus achieving high sample homogeneity and a high survey participation rate. Second, lifestyle-related parameters – such as sleep duration, shift work, and actual use of days off work – were included among the risk factors for first onset of MetS. The association between MetS onset and these factors has not been widely examined, and hours of sleep per day, and days off work, represent two of the key parameters related to lifestyle outside working hours. Therefore, the present study allowed a comprehensive evaluation of factors related to the daily lifestyles of workers that impacted on MetS. Third, the present study examined the effects of the number of high-risk lifestyle parameters on new-onset MetS. Although the effects of individual lifestyle habits on the onset of MetS have been reported previously, this is the first study to have examined the effects of the number of such lifestyle-related factors (including sleep duration, shift work, and actual use of days off).

4.1. Effect of the number of high-risk lifestyle parameters present on incidence of MetS

The present findings suggested that the number of high-risk lifestyle parameters present in any given individual is able to predict the onset of MetS. Previous studies have examined the effects of the number of lifestyle habits on a range of diseases: Breslow et al. examined the association between seven healthy habits and mortality [20]; Morimoto et al. examined the association between eight healthy habits and the onset of cardiovascular diseases [21]; and Ikeda examined the association between six healthy habits and the prevention of lifestyle-related diseases [22]. Wada et al. conducted a seven-year cohort study of 9554 individuals to analyze the association between the three sets of healthy habits proposed by Breslow [20], Morimoto [21], and Ikeda [22], in the studies referred to above, and the onset of MetS. The authors concluded that Ikeda's six healthy habits (smoking, food intake, alcohol intake, exercise, rest, and enjoyable pursuits) [22] had the greatest impact on the risk of MetS, and that there was a significant association between the number of lifestyle habits engaged in and the onset of MetS. In addition to Ikeda's six health-related parameters, the present study revealed that short sleep duration (<5 h) and shift work were additional risk factors for new-onset MetS [23]. These findings give valuable insight into the lifestyle-related parameters affecting the health of workers. Furthermore, the reliability of the current research is high, due to the larger sample size that was employed, in comparison to the study by Wada et al.

From a public health perspective, the current results are significant for a number of reasons. First, it was found that lifestyle-related parameters, which have not conventionally been regarded as important factors in health guidance strategies, such as sleep and actual use of days off work, could prevent the onset of MetS. The authors believe that health guidance on how to improve daily lifestyle should be provided after identifying the factors that can

Table 2
The associations between lifestyle habits at baseline and new-onset obesity, hypertension, hyperglycemia, dyslipidemia, or MetS (1999–2006).

Lifestyle habits at baseline	Obesity[a]			Hypertension[b]			Hyperglycemia[c]			Dyslipidemia[d]			Metabolic syndrome[e]		
	HR	95% CI	*p*	HR	95% CI	*p*	HR	95% CI	*p*	HR	95% CI	*p*	HR	95% CI	*p*
Sleep duration, hours/day			<0.001			<0.001			0.444			0.991			0.001
≥5	1.00			1.00			1.00			1.00			1.00		
<5	1.13	1.06–1.20		0.92	0.88–0.96		0.98	0.91–1.04		1.00	0.95–1.05		1.08	1.03–1.14	
Shift work			0.115			0.018			0.883			0.034			0.029
No shift work	1.00			1.00			1.00			1.00			1.00		
Shift work	1.05	0.99–1.12		1.06	1.01–1.10		1.01	0.94–1.07		1.05	1.00–1.10		1.06	1.01–1.11	
Actual use of weekly rest days			0.039			0.602			0.222			0.016			0.001
Most taken	1.00			1.00			1.00			1.00			1.00		
Most not taken	1.09	1.00–1.19		0.99	0.93–1.04		1.05	0.97–1.14		1.08	1.01–1.14		1.12	1.05–1.19	
Eating in moderation			<0.001			0.040			0.913			0.015			<0.001
Always	1.00			1.00			1.00			1.00			1.00		
Sometimes	1.24	1.15–1.33		1.07	1.01–1.12		1.02	0.95–1.09		1.05	1.00–1.10		1.40	1.33–1.47	
Never	1.30	1.18–1.44		1.03	0.96–1.10		1.00	0.91–1.10		1.10	1.03–1.19		1.53	1.42–1.64	
Taking every opportunity to walk			0.600			0.020			0.061			0.051			0.010
Yes	1.00			1.00			1.00			1.00			1.00		
No	1.02	0.95–1.09		0.95	0.91–0.99		0.94	0.88–1.00		1.05	1.00–1.10		1.07	1.02–1.12	
Drinking			0.026			<0.001			0.338			0.009			<0.001
No drinking	1.00			1.00			1.00			1.00			1.00		
Intake of pure alcohol <60 g/day	0.90	0.83–0.97		1.34	1.26–1.42		0.95	0.88–1.04		0.95	0.89–1.01		0.95	0.89–1.01	
Intake of pure alcohol ≥60 g/day	0.94	0.85–1.05		1.65	1.53–1.78		1.00	0.90–1.11		1.04	0.96–1.12		1.13	1.04–1.22	
Smoking			0.010			0.002			<0.001			<0.001			0.133
No or quit smoking	1.00			1.00			1.00			1.00			1.00		
Number of cigarettes smoked <40/day	0.91	0.85–0.97		0.92	0.88–0.96		1.28	1.20–1.37		1.28	1.22–1.34		0.98	0.94–1.03	
Number of cigarettes smoked ≥40/day	0.92	0.81–1.04		0.94	0.87–1.02		1.43	1.28–1.60		1.34	1.22–1.46		1.08	0.98–1.18	

The analysis was performed after excluding subjects with missing data or subjects with a follow-up period <1 year.
Only male employees were subjected to analysis.
Data for subjects who did not fulfill the criteria for each disease at the baseline were analyzed, and subjects were monitored for new-onset disease over a maximum period of 7 years.
Adjusted factors; obesity: age, hypertension, hyperglycemia, dyslipidemia, mental complaints (irritability, reduced concentration, lethargy).
Hypertension: age, obesity, hyperglycemia, dyslipidemia, mental complaints (irritability, reduced concentration, lethargy).
Hyperglycemia: age, obesity, hypertension, dyslipidemia, mental complaints (irritability, reduced concentration, lethargy).
Dyslipidemia: age, obesity, hypertension, hyperglycemia, mental complaints (irritability, reduced concentration, lethargy).
Metabolic syndrome: age, mental complaints (irritability, reduced concentration, lethargy).
P-value was calculated by Cox proportional hazards model (forced entry method).
Abbreviations: CI, Confidence Interval; HR, Hazard Ratio.
[a] Obesity: BMI ≥25 kg/m^2.
[b] Hypertension: ≥140/90 mmHg, or use of antihypertensive medication.
[c] Hyperglycemia: ≥126 mg/dL, or use of hypoglycemic medication, hypertriglyceridemia: ≥150 mg/dL, Low HDL cholesterol: <40 mg/dL.
[d] Dyslipidemia: hypertriglyceridemia and/or low HDL cholesterol, or use of antilipidemic medication.
[e] Metabolic syndrome: BMI ≥25 kg/m^2 and two or more of the following conditions being met: 1) blood pressure ≥130/85 mmHg, or use of antihypertensive medication, 2) triglyceride ≥150 mg/dL, or HDL cholesterol <40 mg/dL, or use of antilipidemic medication; and 3) glucose ≥110 mg/dL, or use of hypoglycemic medication.

Table 3
The associations between the number of high-risk lifestyle parameters present at baseline and new-onset obesity, hypertension, hyperglycemia, dyslipidemia, or MetS (1999–2006).

Number of high-risk lifestyle parameters at the baseline	Obesity[a]			Hypertension[b]			Hyperglycemia[c]			Dyslipidemia[d]			Metabolic syndrome[e]		
	HR	95% CI	*p*	HR	95% CI	*p*	HR	95% CI	*p*	HR	95% CI	*p*	HR	95% CI	*p*
0–1	1.00		0.002	1.00		0.853	1.00		<0.001	1.00		<0.001	1.00		<0.001
2–3	1.11	1.03–1.18		0.99	0.94–1.04		1.18	1.09–1.26		1.26	1.20–1.32		1.22	1.15–1.29	
4–7	1.18	1.07–1.30		0.98	0.92–1.05		1.20	1.09–1.32		1.42	1.32–1.52		1.43	1.33–1.54	

The analysis was performed after excluding subjects with missing data or subjects with a follow-up period of <1 year.
Only male employees were subjected to analysis.
Data for subjects who did not fulfill the criteria for each disease at baseline were analyzed, and subjects were monitored for new-onset disease over a maximum period of 7 years.
Adjusted factors; obesity: age class, hypertension, hyperglycemia, dyslipidemia, mental complaints (irritability, reduced concentration, lethargy).
Hypertension: age class, obesity, hyperglycemia, dyslipidemia, mental complaints (irritability, reduced concentration, lethargy).
Hyperglycemia: age class, obesity, hypertension, dyslipidemia, mental complaints (irritability, reduced concentration, lethargy).
Dyslipidemia: age class, obesity, hypertension, hyperglycemia, mental complaints (irritability, reduced concentration, lethargy).
Metabolic syndrome: age class, mental complaints (irritability, reduced concentration, lethargy).
P-value was calculated by Cox proportional hazards model (forced entry method).
Abbreviations: CI, Confidence Interval; HR, Hazard Ratio.
[a] Obesity: BMI ≥25 kg/m^2.
[b] Hypertension: ≥140/90 mmHg, or use of antihypertensive medication.
[c] Hyperglycemia: ≥126 mg/dL, or use of hypoglycemic medication, hypertriglyceridemia: ≥150 mg/dL, low HDL cholesterol: <40 mg/dL.
[d] Dyslipidemia: hypertriglyceridemia and/or low HDL cholesterol or use of antilipidemic medication.
[e] Metabolic syndrome: BMI ≥25 kg/m^2, and two or more of the following conditions being met: 1) blood pressure ≥130/85 mmHg, or use of antihypertensive medication, 2) triglyceride ≥150 mg/dL, or HDL cholesterol <40 mg/dL, or use of antilipidemic medication; and 3) glucose ≥110 mg/dL, or use of hypoglycemic medication.

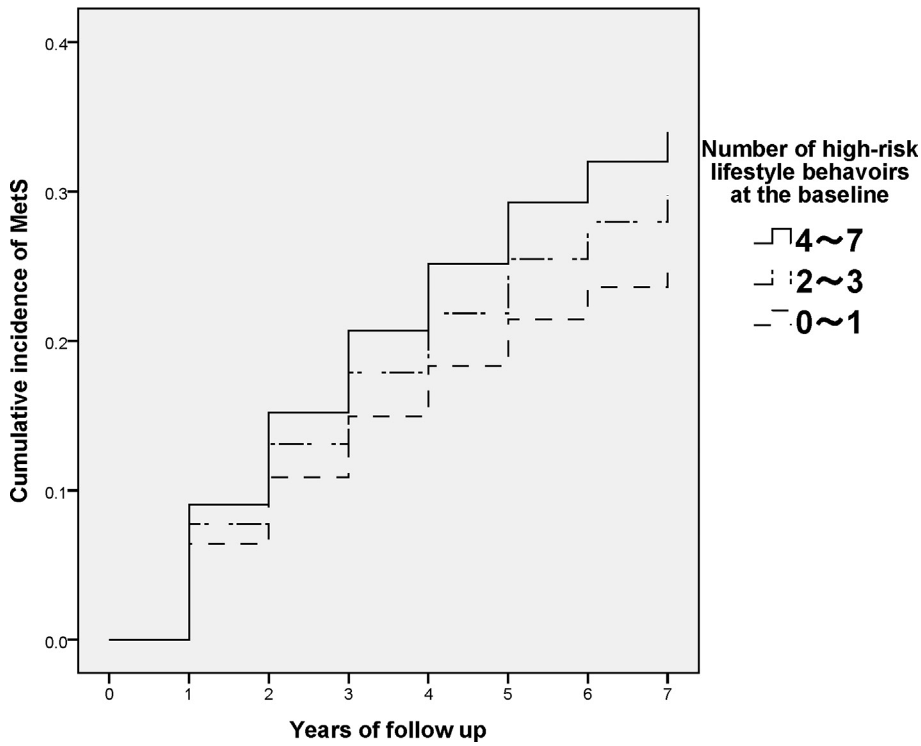

Fig. 1. Kaplan–Meier curves for onset of MetS based on the number of high-risk lifestyle parameters present at the baseline. MetS, metabolic syndrome.

affect workers' health both during and outside working hours, including sleep and days off. Second, the study found that an increase in the number of high-risk lifestyle parameters significantly increased the incidence of MetS onset. Therefore, a comprehensive evaluation of the daily lifestyles of workers may be warranted, with encouragement to decrease the number of risk factors to which they are exposed, and thus helping to reduce the rate of MetS onset. For example, shift work is a risk factor for MetS, and it is important to establish whether shift workers also have other associated risk factors, such as those related to diet or exercise. In addition to the provision of appropriate education and information on the risk of MetS, shift workers should be offered guidance on reducing the number of their risk factors as far as possible, in order to decrease their risk of developing MetS. Currently, Specific Health Checkups and Specific Health Guidance [4] to MetS are widely available in Japan [3], and particular support is provided for patients diagnosed with borderline MetS, in order to reduce or eliminate their risk factors. As part of this health guidance aimed at high-risk patients, it may be effective for counsellors to focus on reducing the number of high-risk lifestyle parameters per patient. Specifically, patients may be able to better understand how they can improve their lifestyle if they are made aware of the number of these high-risk parameters to which they are exposed. Furthermore, improvements in public health require wide dissemination of the relevance of a number of high-risk lifestyle-related factors. It is anticipated that the current findings will contribute to the development of public health strategies (high risk or population approach) aimed at reducing risk factors for MetS in the Japanese population.

4.2. Short sleep duration and MetS

The findings of the present study indicated that short sleep duration was significantly associated with the onset of MetS. Xi et al. conducted a systematic review and meta-analysis of the association between sleep duration and MetS, and identified 12 related studies (10 cross-sectional and two longitudinal) [24]. They then performed a meta-analysis, and found a significant association between short sleep duration and MetS (Odds Ratio 1.27, $p = 0.002$), but no significant association between long sleep duration and MetS. The results of the present study do not contradict the findings of this meta-analysis. However, in comparison with previous studies, the level of epidemiological evidence in the present study was high, due to the large sample size and longitudinal design. There are a number of possible biological mechanisms that might underlie the association between short sleep duration and MetS. It is suggested that short sleep duration increases body weight and changes glucose metabolism [25]. In experimental studies, inadequate sleep significantly changes the main components of energy homeostasis, including glucose tolerance, food craving, and hormones critical to appetite regulation [26]. For instance, sleep restriction could reduce leptin and elevate ghrelin, which regulate satiety and hunger, respectively [27], thereby increasing the cravings for calorie-dense and carbohydrate-rich food.

4.3. Shift work and MetS

The present study indicated that shift work significantly promoted the onset of MetS. In a systematic review on the association between shift work and MetS, Canuto et al. selected 10 studies (three longitudinal, six cross-sectional, and one case–control study) and found a positive association between shift work and MetS in eight of them [28]. However, only three of the studies included sleep duration as a confounding variable, and the findings of the studies were contradictory. Canuto et al. concluded that there was insufficient epidemiological evidence for a correlation between shift work and onset of MetS, and identified three desirable prerequisites for epidemiological studies investigating this association: (1) a sufficiently large sample size; (2) a clear definition of shift work (night work only or rotating shifts); and (3) inclusion of sleep duration as a confounder.

The present longitudinal study satisfied all of these conditions and is one of the highest-quality epidemiological studies to have investigated the association between shift work and MetS onset. The effect of shift work on cardiovascular risk factors may be attributable to a disturbance of circadian rhythm. It is well established that mice with mutation in the Clock gene, which regulates circadian rhythm, tend to develop dyslipidemia and hyperglycemia [29]. Other studies have also suggested that circadian rhythm disturbance may induce MetS [30–32]. Steals has noted that there is interplay between the metabolic pathways associated with lipogenesis and catabolism, involving the glucocorticoid receptor, peroxisome proliferator-activated receptors α and γ, and the Clock gene. Disruption of these pathways leads to onset of MetS [33].

4.4. Actual use of weekly rest days and MetS

The present study demonstrated a significant association between actual use of weekly rest days and new-onset MetS. A number of epidemiological studies have reported an association between working hours and MetS [34–37]. Although resting status is, effectively, the opposite of working status, few studies have investigated the effects of actual use of weekly days off. It has previously been reported that insufficient use of days off significantly promoted MetS onset [13], and these findings were corroborated by the present study. Importantly, the present study had higher data reliability, and resolved the limitations of earlier research, suggesting that weekly days off are not simply days off work but have a direct effect on the health status of workers. However, the present study did not identify the physiological mechanism whereby insufficient use of weekly days off increases the risk of MetS onset.

In addition to weekly days off, generally corresponding to 1 or 2 days of rest from work per week, workers can take longer periods off work as vacations. Gump et al. studied the effects of vacations on health, and followed up 12,338 middle-aged men at high risk of cardiovascular disease in the United States for 9 years [38]. In comparison with men who did not take annual vacations, the relative risk of all-cause mortality for subjects who did take annual vacations was 0.83, and the relative risk of mortality due to cardiovascular disease and non-cardiovascular disease was 0.71 and 0.98, respectively. Gump et al. argued that vacationing could release subjects from continuous or potential stress that might trigger or exacerbate coronary heart disease, and concluded that vacationing may offer opportunities for social contact with family members and friends and for physical activities, thus also allowing physiological recovery. Weekly days off may confer benefits similar to those of vacationing. However, the underlying mechanisms of any such beneficial effects have not yet been clarified, and further epidemiological and physiological data are required.

4.5. Limitations

The present study had a number of limitations. First, as it was retrospective and utilized previously collected data, not all the necessary data were included in the questionnaire. For example, it did not consider data on how leisure time was spent on weekly days off. Therefore, the effects of different types of leisure time could not be analyzed. Furthermore, the data relating to weekly days taken off work were only available for a limited period of time – 1–2 months before the subjects were asked about it. Therefore, it is possible that any health problems resulting from difficulties in taking weekly days off in the mid-term to long-term may not have been evaluated. Second, some of the data, including those pertaining to taking weekly days off work, sleep duration, and smoking habits, were obtained by a self-administered questionnaire and could not be independently verified. A prospective study including these parameters would therefore be useful for corroborating the findings.

5. Conclusions

In conclusion, the present study demonstrated that several lifestyle-related parameters, including sleep duration, shift work, and days off, are risk factors for new-onset MetS, and that an increase in the number of these high-risk lifestyle parameters in any given individual further increases the risk of developing MetS. Therefore, it is important to comprehensively evaluate the daily living habits of workers, and also consider lifestyle-related parameters that have not traditionally been targeted by health guidance, such as sleep duration and days off, in order to devise strategies for the prevention of MetS using multiple approaches.

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Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2017.07.027.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.sleep.2017.07.027.

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