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The association of work-related stressors and their changes over time with the development of metabolic syndrome: The Furukawa Nutrition and Health Study

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Abstract: Objective: To investigate associations of work-related stressors and their changes over time with the risk of developing metabolic syndrome (MetS) among Japanese manufacturing workers. **Methods:** Participants were 1,040 employees aged 19 to 68 years who were free from MetS at baseline and completed the three year-interval follow-up survey. MetS was defined according to the Joint Interim Statement. Work-related stressors (job strain, job demands, job control, and worksite social support) were assessed based on the Job Content Questionnaire and were split into two categories (low and high) by the median value at each survey. Multivariable logistic regression was performed to investigate the associations of baseline work-related stressors and their changes over time with the incidence of MetS. **Results:** Three years later, 61 workers developed MetS. Higher job demands at baseline were significantly associated with a lower risk of MetS (adjusted odds ratio 0.46, 95% confidential interval: 0.24, 0.89). In the analyses of the changes in stressors over time, those whose job demands changed from low to high showed significantly higher risk of MetS (adjusted odds ratio 3.27, 95% confidential interval: 1.46, 7.34), compared with those who reported low job demands in both surveys. **Conclusions:** Results suggest that an increase in job demands over time, but not higher job demands at baseline, is associated with increased risk of MetS.

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Key words: Job Content Questionnaire, Job demands, Metabolic syndrome, Prospective study, Workplace, Work-related stressors

Introduction

Work-related stress is the response people may have when presented with work demands and pressures that are not matched to their knowledge and abilities and which challenge their ability to cope[1]. Previous systematic reviews and meta-analyses of longitudinal studies have shown significant associations between high job strain and the risk of cardiovascular disease (CVD), including coronary heart disease[2,3]. A systematic meta-analysis suggested that job strain is a risk factor for hypertension[4], and a prospective study also found a dose-response relationship between job strain and the risk of obesity[5]. Job strain has been assessed by using Job Content Questionnaire (JCQ) based on the Karasek's demands-control model[6,7]. Worksite social support is a third dimension of this model, and low social support may increase the risk of illness or worsen the course of an illness in a high job strain situation[7].

Metabolic syndrome (MetS) is an important underlying

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condition of CVD events[8-10]. To our knowledge, only three longitudinal studies[11-13] and one cross-sectional study[14] have investigated the association between job strain and MetS, and all reported significant associations. Chandola et al. reported a dose-response relationship between the exposure to iso-strain (i.e., high job strain plus low work social support) and the risk of MetS over 14 years of follow-up among men and women in the United Kingdom[11]. The two other prospective studies investigated the association of job strain and subscales of JCQ at baseline with the risk of MetS[12,13]. One study in the United States found a significant association between an active job (i.e., high job demands-high control) in men, high job strain in women, or high job demands in men and the risk of MetS[12]. Another study in Italy indicated the significant association of a high work stress (i.e., high job strain or high effort-reward ratio) and high job demands with the risk of MetS among male police officers[13].

Although these western studies support a role for work-related stressors in the development of MetS, several questions remain unanswered. First, there may be cultural diversity in the reaction of workers against their workload. Inoue et al.[15] showed that workload was positively associated with work engagement among Japanese employees, and suggested that workplace structures in Japanese organizations are more vertical and hierarchical compared to those in European countries. Therefore, the effect of work-related stressors on the development of MetS may differ between Japan and western countries. Thus, there is a need for studies of work-related stressors and MetS development in Asian countries, including Japan. Second, existing studies have only measured work-related stressors at baseline[12,13] or as the total amount of exposure during follow-up[11]. Currently, workers are exposed to a work environment that can rapidly change due to new technologies, organizational changes, or other challenges;[16] and work-related stressors can change over time[17]. Thus, it is important to assess the effect of changes in work stressors over time on the risk of MetS.

To address these issues, we investigated the association of job strain and each component of the JCQ scale (i.e., job demands, job control, and worksite social support) at baseline and over time with the onset of MetS among Japanese employees.

Methods

Study design

We used data from the Furukawa Nutrition and Health Study, which has been described elsewhere[18,19]. Briefly, a baseline health survey was conducted during a periodic health checkup in 2012 and 2013 among workers of a manufacturing company and its affiliated companies (workplace A in Chiba prefecture and workplace B in Kanagawa prefecture). Three years later, the second survey was conducted. In both surveys, we assessed work-related stressors and lifestyle factors, and obtained health examination data including anthropometric and biochemical data and medical history. The research staff checked the questionnaires for completeness, and if necessary, asked participants to clarify their responses.

Participants

Of the 2,828 workers at baseline, 2,162 (1,930 men and 232 women, aged 18-70 years) agreed to participate in the study (participation rate = 76.4%). Participants filled out two types of study-specific questionnaires: one for diet and another for health-related lifestyle. Of these, we excluded 152 people who lacked information on any component of MetS, and 261 people who met the criteria for MetS at baseline. From the remaining participants, we excluded people who had a history of cancer (n = 15), cardiovascular disease (n = 11), chronic hepatitis (n = 2), chronic pancreatitis (n = 3), or kidney disease (n = 4) at baseline, because people with such diseases might be under special consideration with regards to their job assignments (for instance, reduced workload). Of the remaining 1,714 people, we excluded those who had missing data on the JCQ scales (n = 44) and covariates (n = 35) at baseline. 1,065 employees agreed to participate in the second survey (follow-up rate = 64.8%). We then excluded 15 people who lacked information on any component of MetS at the time of the second survey. Of the remaining 1,050 people, we sequentially excluded those who had missing data on the JCQ scales (n = 4) and covariates (n = 6) at the second survey, leaving 1,040 participants (925 men and 115 women) aged 19 to 68 years in the analyses. The study protocol was approved by the Ethics Committee of the National Center for Global Health and Medicine, Japan. Written informed consent was obtained from each participant.

Anthropometric and biochemical measurement

The participants wore light clothes and no shoes, and their height and body weight were measured to the nearest 0.1 cm and 0.1 kg, respectively. Body mass index (BMI) was calculated as the body weight in kilograms divided by the square of the body height in meters. Waist circumference was measured at the umbilical level in the standing position using a measuring tape. Systolic and diastolic blood pressures were measured with an automated sphygmomanometer (BP 103 i II at workplace A and HEM-907 at workplace B, Omron Health Care Co. Ltd., Kyoto, Japan). Plasma glucose concentration was assayed enzymatically using the Quick-auto-neo-GLU-HK (Shino-Test Corp., Tokyo, Japan). High-density lipoprotein (HDL) cholesterol level was measured by a direct enzymatic method using Cholestest N-HDL (Sekisui Medical Co. Ltd., Japan) at workplace A and the

Metabolead-HDL-C (Kyowa Medex Co. Ltd., Japan) at workplace B. Triacylglycerol level was measured by an enzymatic method using Pureauto S TG-N (Sekisui Medical Co. Ltd., Japan) at worksite A and Determiner TG (Kyowa Medex Co. Ltd, Japan) at worksite B. All laboratories involved in the health checkups in the participating companies have received satisfactory results (rank A or score >95 out of 100) from external quality control surveillance including those by the Japan Medical Association, the Japanese Association of Laboratory Medical Technologists, and the National Federation of Industrial Health Organization.

Definition of metabolic syndrome

We defined MetS according to the Joint Interim Statement of the International Diabetes Federation and the American Heart Association/National Heart, Lung, and Blood Institute[20]. We defined MetS as those who had any three or more of the following criteria: (1) large waist circumference for Asians: ≥90 cm in men and ≥80 cm in women; (2) high triacylglycerol: ≥150 mg/d*l*; (3) low high-density lipoprotein (HDL)-cholesterol: <40 mg/d*l* in men and <50 mg/d*l* in women; (4) high blood pressure: systolic blood pressure ≥130 mmHg and/or a diastolic blood pressure ≥85 mmHg; and (5) high fasting blood glucose: ≥100 mg/d*l*. Participants currently receiving antihypertensive medication, those currently receiving a lipid-lowering drug, and those with a history of diabetes were also considered to meet the criteria for high blood pressure, high triacylglycerol, and high fasting glucose, respectively.

Definition of work-related stressors

We used the 22-item Japanese version of the JCQ, which has confirmed reliability and validity[21]. The response for each item is a 4-point Likert scale ranging from 1 for "strongly disagree" to 4 for "strongly agree", and the sum of the weighted scores is used as the score[21]. The JCQ includes the following scales: job demands (5 items, range 12-48); job control (9 items, range 24-96); job strain, which is calculated by the job demands score divided by half of the job control score (range 0.25-4.0)[21,22]; and worksite social support, which is composed of two subscales, namely, supervisor support and coworker support (8 items, range 0-32).

Levels of job strain, job demands, job control, and worksite social support were classified into high and low levels by the median value in each survey. The medians of each JCQ scale at baseline and the second survey were the same: 0.94 in job strain, 31 in job demands, 68 in job control, and 23 in worksite social support. To estimate the effect of changes in work-related stressors, we created four groups according to the combinations of stress levels in two surveys: high-high, high-low, low-high, and low-low for each JCQ scale[17]. Workers with low-low in job strain, low-low in job demands, high-high in job control, and high-high in worksite social support were grouped as a "stable low stressor", in harmony with existing literature[17]. Similarly, workers with low-high in job strain, low-high in job demands, high-low in job control, and high-low in worksite social support were grouped as a "change into high stressor". Workers with high-low in job strain, high-low in job demands, low-high in job control, and low-high in worksite social support were grouped as a "change into low stressor". High-high in job strain, high-high in job demands, low-low in job control, and low-low in worksite social support were grouped as a "stable high stressor".

Other covariates

Work-related and leisure-time physical activities were both expressed as the sum of the metabolic equivalent (MET) values multiplied by the duration of time engaged in activities of varying intensity. The work-related activities included occupational work, domestic housework, and commuting to and from work. The energy intake (kcal/day) during the preceding one-month period was estimated using a validated brief self-administered diet history questionnaire which includes 58 food and beverage items[23]. Age and sex were obtained from the health checkup in each survey. With the exception of age, sex, and site, all of the covariates described below were ascertained via a lifestyle questionnaire designed for this study[18,19]. The baseline covariates included in the analyses were age (years), sex (men or women), site (workplace A or workplace B), family structure (living alone, or living with family/other), marital status (married or other), occupational category (blue collar or white collar), work status (standard or non-standard/part time), night and rotating shift work (yes or no), work-related physical activity (<3, 3-6, 7-19, or ≥20 METs-h/d), leisure-time physical activities (not engaged, 1-2, 3-9, or ≥10 METs-h/week), smoking (never-smoker, former smoker, or current smoker), alcohol drinking (never, occasionally, <23 g ethanol/day, or ≥23 g ethanol/day), sleep duration (<6, 6-6.9, or ≥7 h/d), and quality of sleep (good or poor).

Statistical analysis

We first examined the association between JCQ scales at baseline and the risk of MetS by multiple logistic regression analysis, and calculated the adjusted odds ratios (ORs) and 95% confidence intervals (CIs) of MetS for the JCQ scales at baseline, using the lower level of the JCQ scales as a reference. Then, we performed the main analysis to investigate the association between changes in each of the JCQ items and the onset of MetS, using the "stable low stressor" group as a reference. Model 1 was adjusted for age, sex, and site. Model 2 was further adjusted for family structure, marital status, occupational category, work status, night and rotating shift work, work-related

Table 1. Baseline characteristics of study participants who did and did not develop metabolic syndrome

	MetS	Without MetS
No. of subjects	61	979
Men	57 (93.4)	868 (88.7)
Age (years), mean ± SD	44.1 ± 8.8	41.8 ± 8.4
Workplace A (survey in April 2012)	37 (60.7)	526 (53.7)
Living alone	14 (23.0)	160 (16.3)
Married	44 (72.1)	738 (75.4)
Work status (non-standard or part time)	9 (14.8)	43 (4.4)
Occupational category (blue collar)	36 (59.0)	413 (42.2)
Night and rotating shift work (yes)	13 (21.3)	213 (21.8)
Work-related physical activity (≥20 METs- hours/day)	21 (34.4)	225 (23.0)
Leisure-time physical activity (≥10 METs- hours/day)	14 (23.0)	267 (27.3)
Current smoker	24 (39.3)	282 (28.8)
Alcohol drinker (≥23g of ethanol/day)	16 (26.2)	259 (26.5)
Sleep duration (<6 h/day)	22 (36.1)	378 (38.6)
Quality of sleep (poor)	16 (26.2)	323 (33.0)
Energy intake (kcal/day), mean ± SD	1834 ± 576	1777 ± 487
Body mass index (kg/m^2), mean ± SD	25.7 ± 3.6	22.4 ± 2.7
Waist circumference (cm), mean ± SD	89.1 ± 8.4	79.6 ± 7.6
Systolic blood pressure (mmHg), mean ± SD	131.2 ± 16.9	121.2 ± 16.0
Diastolic blood pressure (mmHg), mean ± SD	80.6 ± 10.3	74.2 ± 11.0
Triacylglycerol (mg/d*l*), median (IQR)	136 (101, 187)	81 (59, 114)
HDL cholesterol (mg/d*l*), mean ± SD	53.6 ± 13.9	65.3 ± 15.5
Fasting blood glucose (mg/d*l*), mean ± SD	93.9 ± 11.7	89.1 ± 9.7
Job strain[†]	0.96 ± 0.25	0.97 ± 0.24
Job demands	30.6 ± 5.3	31.5 ± 5.3
Job control	56.8 ± 11.5	67.1 ± 11.6
Worksite social support	23.0 ± 3.9	22.8 ± 3.7

MetS, metabolic syndrome; SD, standard deviation; IQR, interquartile range (25th percentiles, 75th percentiles)
Data are number (percentages) unless otherwise specified.
[†]Job strain at baseline was calculated as the ratio of the job demands score to half the job control score (= job demands score/ 0.5x job control score).

physical activity, leisure-time physical activities, smoking, alcohol drinking, sleep duration, quality of sleep, waist circumference (cm), triacylglycerol (log-transformed mg/d*l*), high-density lipoprotein cholesterol (mg/d*l*), systolic blood pressure (mmHg), and fasting blood glucose (mg/d*l*) at baseline. We did not include BMI and diastolic blood pressure as covariates because they were highly correlated with waist circumference and systolic blood pressure, respectively. We repeated the above analyses by entering changes of each stressor as a continuous scale after standardization (mean = 0, standard deviation [SD] = 1). If there was a significant association of the change of each stressor with the onset of MetS in the main analysis, we further investigated the association between stressor changes and components of MetS risk (i.e., high waist circumference, high blood pressure, high triacylglycerol, low HDL cholesterol, and high fasting blood glucose), with adjustment for covariates and the same MetS-component value (continuous) at baseline.

To investigate the potential role of lifestyle factors underlying the association, we investigated the association between changes in stressors and selected lifestyle changes (i.e., physical activity, smoking, alcohol drinking, sleep duration, and energy intake). If a lifestyle factor shows a significant difference among the stressor groups, we then examined the stressor-MetS association with additional adjustment for the lifestyle change.

Two-sided *p*-values <.05 were regarded as statistically significant. All analyses were performed using statistical software Stata version 15.0 (StataCorp, College Station, Texas, USA).

Table 2. Adjusted odds ratio and 95% confidence interval for the onset of metabolic syndrome for high versus low stressor groups†

	Cases of MetS/total (%)	Model 1	Model 2
		OR (95% CI)	OR (95% CI)
Job strain‡			
Low	33/521 (6.3)	Reference	Reference
High	28/519 (5.4)	0.89 (0.53, 1.50)	0.66 (0.34, 1.28)
Job demands			
Low	40/541 (7.4)	Reference	Reference
High	21/499 (4.2)	0.56 (0.32, 0.96)	0.46 (0.24, 0.89)
Job control			
Low	36/562 (6.4)	1.32 (0.77, 2.24)	0.95 (0.48, 1.89)
High	25/478 (5.2)	Reference	Reference
Worksite social support			
Low	31/542 (5.7)	0.94 (0.56, 1.58)	0.64 (0.34, 1.24)
High	30/498 (6.0)	Reference	Reference

MetS, metabolic syndrome; OR, adjusted odds ratio; CI, confidence interval

†The high and/or low stressor groups were decided by the median of the Job Content Questionnaire scales at baseline.

‡Job strain at baseline was calculated as a ratio of the job demands score to half of the job control score (= job demands score/ 0.5 x job control score).

Model 1, adjusted for age (years), sex (men or women), and site (workplace A or workplace B) at baseline.

Model 2, adjusted for Model 1 + family structure (living alone, or living with family/other), marital status (married or other), occupational category (blue collar or white collar), work status (standard or non-standard/part time), night and rotating shift work (yes or no), work-related physical activity (<3, 3-6, 7-19, or ≥20 METs-h/d), leisure-time physical activity (not engaged, 1-2, 3-9, or ≥10 METs-h/week), smoking (never, past, or current smoker), alcohol drinking (never, occasionally, <23g ethanol/day, or ≥23g ethanol/day), sleep duration (<6, 6-6.9, or ≥7 h/d), quality of sleep (good or poor), energy intake (kcal/day), waist circumference (cm), triacylglycerol (log-transformed mg/d*l*), high-density lipoprotein cholesterol (mg/d*l*), systolic blood pressure (mmHg), and fasting blood glucose (mg/d*l*) at baseline.

Results

Table 1 presents the baseline characteristics of the 1,040 employees according to the onset of MetS. Workers who developed MetS tended to be older, living alone, blue-collar, high in work-related physical activity but low in leisure time physical activity, and current smokers as compared with the workers who did not develop MetS.

Table 2 shows ORs for the onset of MetS according to baseline work-related stressor level. Job strain, job control, and worksite social support did not show any statistically significant association with the onset of MetS. High job demands at baseline were associated with a significantly lower risk of MetS compared to the low job demands in Model 2 (OR 0.46, 95% CI: 0.24, 0.89).

As Table 3 shows, those who experienced increased job demands (change into high stressor) showed a significantly higher risk of MetS (OR 3.27, 95% CI: 1.46, 7.34) compared with those who reported low job demands in both surveys (stable low stressor) in Model 2. Changes in job strain, job control, and worksite social support over time were not significantly associated with the onset of MetS. The associations with the changes of stressors on a continuous scale are shown in Supplementary Table 1. The OR of MetS was 1.49 (95% CI: 1.04, 2.14) per 1 SD increase in job demands, whereas there was no significant association of job strain, job control, and worksite social support with the onset of MetS.

As Table 4 shows, those who experienced increased job demands (change into high stressor) showed a significantly higher risk of developing of high fasting blood glucose compared to those who reported low job demands in both surveys (stable low stressor) (OR 3.86, 95% CI: 1.77, 8.38). However, individuals whose job demand decreased (change into low stressor) between the two surveys and those whose job demand was high in both surveys (stable high stressor) had a lower risk of a large waist circumference (OR 0.34, 95% CI: 0.12, 0.95 in change into low stressor; OR 0.39, 95% CI: 0.16, 0.91 in

Table 3. Adjusted odds ratio and 95% confidence interval for the changes of stressors† between baseline and the second survey and the onset of metabolic syndrome

	Stable low stressor	Change into high stressor	Change into low stressor	Stable high stressor
Job strain‡	Low-low	Low-high	High-low	High-high
Cases of MetS /total (%)	19/354 (5.4)	14/167 (8.4)	9/171 (5.3)	19/348 (5.5)
Model 1 OR (95% CI)	Reference	1.74 (0.85, 3.58)	0.97 (0.43, 2.20)	1.15 (0.59, 2.24)
Model 2 OR (95% CI)	Reference	1.93 (0.79, 4.69)	0.82 (0.32, 2.11)	0.86 (0.37, 1.99)
Job demands	Low-low	Low-high	High-low	High-high
Cases of MetS /total (%)	20/371 (5.4)	20/170 (11.8)	8/175 (4.6)	13/324 (4.0)
Model 1 OR (95% CI)	Reference	2.61 (1.35, 5.06)	0.84 (0.36, 1.94)	0.80 (0.39, 1.65)
Model 2 OR (95% CI)	Reference	3.27 (1.46, 7.34)	0.73 (0.28, 1.90)	0.75 (0.31, 1.78)
Job control	High-high	High-low	Low-high	Low-low
Cases of MetS /total (%)	16/347 (4.6)	9/131 (6.9)	7/121 (5.8)	29/441 (6.6)
Model 1 OR (95% CI)	Reference	1.56 (0.67, 3.63)	1.27 (0.51, 3.18)	1.58 (0.84, 3.00)
Model 2 OR (95% CI)	Reference	1.55 (0.56, 4.28)	1.21 (0.42, 3.53)	1.06 (0.46, 2.44)
Worksite social support	High-high	High-low	Low-high	Low-low
Cases of MetS /total (%)	17/304 (5.6)	13/194 (6.7)	7/141 (5.0)	24/401 (6.0)
Model 1 OR (95% CI)	Reference	1.22 (0.58, 2.60)	0.84 (0.34, 2.07)	1.09 (0.57, 2.07)
Model 2 OR (95% CI)	Reference	1.02 (0.40, 2.60)	0.51 (0.17, 1.53)	0.70 (0.31, 1.60)

MetS, metabolic syndrome; OR, adjusted odds ratio; CI, confidence interval

†We classified high and low groups by the median of the Job Content Questionnaire scales at baseline and at the second survey.

‡Job strain was calculated as a ratio of the job demands score to half the job control score (= job demands score / 0.5 x job control score).

Model 1, adjusted for age (years), sex (men or women), and site (workplace A or workplace B) at baseline.

Model 2, adjusted for Model 1 + family structure (living alone, or living with family/other), marital status (married or other), occupational category (blue collar or white collar), work status (standard or non-standard/part time), night and rotating shift work (yes or no), work-related physical activity (<3, 3-6, 7-19, or ≥20 METs-h/d), leisure-time physical activity (not engaged, 1-2, 3-9, or ≥10 METs-h/week), smoking (never, past, or current smoker), alcohol drinking (never, occasionally, <23g ethanol/day, or ≥23g ethanol/day), sleep duration (<6, 6-6.9, or ≥7 h/d), quality of sleep (good or poor), energy intake (kcal/day), waist circumference (cm), triacylglycerol (log-transformed mg/d*l*), high-density lipoprotein cholesterol (mg/d*l*), systolic blood pressure (mmHg), and fasting blood glucose (mg/d*l*) at baseline.

stable high stressor).

The increase in energy intake between the two surveys among individuals with increased job demands (change into high stressor) was significantly greater than that among those with low job demands in both surveys (stable low stressor) (Supplementary Table 2). Additional adjustment for changes in energy intake did not materially alter the association of the increase in job demands with the risk of MetS (from OR 3.27, 95% CI: 1.46, 7.34 to OR 3.12, 95% CI: 1.38, 7.05; data not shown in Table). Other lifestyles were not significantly associated with changes in job demands.

Discussion

This study among Japanese employees showed that job strain, job control, and worksite social support at baseline and changes in these stressors over time were not significantly associated with the onset of MetS. Higher job demands at baseline were associated with a lower risk of MetS, but increases in job demands over time were associated with a higher risk of MetS. To our knowledge, this is the first study to investigate the association between changes in work-related stressors over time and the onset of MetS.

Our finding of no association between job strain at baseline and the onset of MetS conflicts with the findings of two longitudinal studies, which reported positive associations between job strain and MetS[12,13]. The inconsistency between the current study and previous studies could be partly explained by the difference in age, sex, and occupation of study participants. In the present study, 43.2% were blue-collar workers among men and women aged 19 to 68 years (average age of 41.9 years) in a manufacturing company. However, the participants in the US study were men and women aged 30-40 years in diverse occupational groups[12], and participants in the Italian study were male police officers with an average age of 35.4 years[13].

The longitudinal studies in western countries showed that high job demands at baseline were significantly associated with an increased risk of MetS[12,13]. In contrast, the

Table 4. Adjusted odds ratio and 95% confidence interval for changes in job demands† and the risks of each component of metabolic syndrome

	Low-low	Low-high	High-low	High-high
High waist circumference				
Cases (% of 923 subjects)	32 (9.5)	13 (8.9)	10 (6.8)	17 (5.8)
OR (95% CI)	Reference	0.56 (0.21, 1.49)	0.34 (0.12, 0.95)	0.39 (0.16, 0.91)
High blood pressure				
Cases (% of 720 subjects)	33 (13.5)	18 (14.2)	20 (17.2)	31 (13.3)
OR (95% CI)	Reference	1.13 (0.54, 2.36)	1.25 (0.62, 2.53)	0.89 (0.47, 1.67)
High triacylglycerol				
Cases (% of 869 subjects)	33 (10.7)	24 (16.8)	14 (9.7)	29 (10.6)
OR (95% CI)	Reference	1.36 (0.71, 2.60)	0.97 (0.46, 2.03)	0.90 (0.48, 1.66)
Low HDL cholesterol				
Cases (% of 1017 subjects)	15 (4.1)	8 (4.9)	3 (1.8)	9 (2.9)
OR (95% CI)	Reference	2.48 (0.61, 10.1)	0.35 (0.07, 1.85)	1.24 (0.34, 4.52)
High fasting blood glucose				
Cases (% of 939 subjects)	18 (5.5)	19 (12.1)	12 (7.8)	15 (5.0)
OR (95% CI)	Reference	3.86 (1.77, 8.38)	1.20 (0.52, 2.76)	0.95 (0.43, 2.09)

OR, adjusted odds ratio; CI, confidence interval

†We classified high and low groups by the median of the job demands scores at baseline and at the second survey. We excluded participants who exhibited each respective component of metabolic syndrome at baseline.

High waist circumference for Asians: ≥90 cm in men and ≥80 cm in women; high blood pressure: systolic blood pressure ≥130 mmHg and/or a diastolic blood pressure ≥85 mmHg; high triacylglycerol: ≥150 mg/d*l*; low high-density lipoprotein (HDL) -cholesterol: <40 mg/d*l* in men and <50 mg/d*l* in women; and high fasting blood glucose: ≥100 mg/d*l*.

Model was adjusted for age (years), sex (men or women), site (workplace A or workplace B), family structure (living alone, or living with family/other), marital status (married or other), occupational category (blue collar or white collar), work status (standard or non-standard/part time), night or rotating shift work (yes or no), work-related physical activity (<3, 3-6, 7-19, or ≥20 METs-h/d), leisure-time physical activity (not engaged, 1-2, 3-9, or ≥10 METs-h/week), smoking (never, past, or current smoker), alcohol drinking (never, occasionally, <23g ethanol/day, or 23g ethanol/day), sleep duration (<6, 6-6.9, or ≥7 h/d), quality of sleep (good or poor), energy intake (kcal/day), and each component of metabolic syndrome (continuous) at baseline.

present study found that high job demands at baseline were significantly associated with a decreased risk of MetS, a finding in line with Japanese cross-sectional studies showing an inverse association of working hours with hypertension[24] and type 2 diabetes[25]. Japanese organizations tend to be more vertical and hierarchy-oriented than European organizations, and being busy at work may create a feeling of importance for Japanese workers[15]. The differences in workplace culture between Japan and western countries may account for the discrepancy in the association.

We also found that an increase in job demands over time was associated with a higher risk of MetS and high fasting blood glucose. The seemingly inconsistent findings between the cross-sectional and longitudinal association analyses could be explained by the adaptation theory[26]. Adaptation to the distress caused by an increase in workload may increase secretion of stress hormones (i.e., cortisol)[26], which are positively correlated with glucose, HOMA-IR, and waist circumference[27].

There are several possible explanations regarding the potential role of lifestyle factors underlying the association of increased job demands with MetS risk. An increase in job demands was significantly associated with an increase in energy intake compared to those with stable low job demands. However, the adjustment for the change in energy intake during the two surveys did not materially attenuate the association of increased job demands with the risk of MetS. Thus, the increase in energy intake is not a mediator of the association between increased job demands and MetS risk.

The strengths of this study include a prospective design using the validated JCQ scale[23], and controlling for a number of confounders. In addition, the present study used 3 year follow-up data, which may reduce the risk of reverse causality. Nevertheless, this study has some limitations. First, we could not assess what type of change in the work environment increased job demands (e.g., a change in the work place or the workload) due to the limited information in this study. Second, this study did not adjust for potentially important confounding factors including work- or finance-related stressful life events which may predict poor metabolic health[28]. Finally, caution is required in generalizing these findings, since the results were from Japanese workers who were employed by a manufacturing company. Additionally, these results might largely reflect characteristics of male workers, since this study was performed among Japanese employees at a male-dominated manufacturing company[18,19].

In conclusion, this longitudinal study indicates that workers who experienced increased job demands might have a high risk of developing MetS.

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