A Longitudinal Study on the Effect of Shift Work on Weight Gain in Male Japanese Workers

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Objective: This study compared the effect of alternating shift work and day work on weight gain in Japanese male workers.

Methods and Procedures: A longitudinal cohort study was conducted in day workers (n = 4,328) and alternating shift workers (n = 2,926) of a steel company who received annual health checkups over a 14-year period between 1991 and 2005. The association between the type of job schedule and weight gain was investigated using multivariate pooled logistic regression analyses. The endpoints in the study were either a 5, 7.5, or 10% increase in BMI during the period of observation, compared to the BMI at entry.

Results: The type of job schedule was significantly associated with all three BMI endpoints (5% increase in BMI; odds ratio (OR) for comparison between alternating shift workers and regular day workers, 1.14; 95% confidence interval (CI), 1.06–1.23): (7.5% increase in BMI; OR, 1.13; 95%CI, 1.03–1.24: 10% increase in BMI; OR, 1.13; 95%CI, 1.00–1.28). BMI at study entry was also positively associated with the 5, 7.5, and 10% increases in BMI during the study. On the other hand, age and drinking habits were negatively associated with 5, 7.5, and 10% increases in BMI.

Discussion: Our study revealed that alternating shift work was an independent risk factor for weight gain in male Japanese workers. Efficient health screening and regular checkups, combined with support to control unhealthy lifestyle factors, would be of considerable benefit for maintaining the health of Japanese shift workers.

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INTRODUCTION

Industrialization in Japan and other countries has given rise to the widespread adoption of 24-h continuous operations in a number of industries, including mining, manufacturing, transportation, and service-type industries. This has resulted in an increase in the proportion of the population routinely engaged in shift work (1,2). In addition to day work, other schedules commonly employed include fixed night work and alternating shift work. The Ministry of Health, labor, and Welfare reported that 22.7% of Japanese companies employed shift workers in 2005 (ref. 2). The proportion of larger companies using shift workers has increased, with 51.2% of companies with at least 1,000 employees having adopted a shift work schedule that includes fixed night work and alternating shift work (2). An investigation on the effect of shift work on the health of workers is therefore urgent and important. The effect of shift work on health has been studied extensively. An association between shift work and high blood pressure has been reported in several studies (3–9), with disturbed circadian rhythms, sleep and lifestyle problems, and increased stress being implicated as possible risk factors for disease in shift workers (3,10). Other studies have also reported that elevated serum triglycerides (11–14) and lower concentrations of high-density lipoprotein cholesterol (11,12) tend to occur more frequently in association with shift work than with fixed daytime work. In addition, several cohort studies have reported an association between shift work and abnormal glucose metabolism (15,16), suggesting that there may be an association between shift work and development of the metabolic syndrome.

On top of these changes in work schedules, modernization of life style characterized by the development of transport systems, an environment that promotes sedentary behavior, and a high intake of fat has led to a marked increase in the prevalence of obesity. Obesity has become a major public health concern as a lifestyle-related disease in Japan and many industrialized countries, with several studies reporting that average BMI is increasing (17–21). The effect of shift work on body weight has been investigated in previous studies, several of which demonstrated a significant effect of shift work on body weight and also the tendency to become overweight (11,22–26). In contrast,

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other studies failed to show such associations (12,13,27). As all of these studies were cross-sectional in design, the relationship between shift work and body weight was not determined conclusively. Several long-term follow-up studies (28–30) have also investigated the risk of obesity or weight gain in shift workers. However, two of those studies could not rule out the bias due to the dropout, given that the studies were based on only two or three intermittent measurements (29,30). The third of these studies did not show any effect of shift work on obesity (28). These results prompted us to conduct a cohort study to clarify the effect of shift work on body weight. The study used a pooled logistic regression model, which took into account the effect of confounding influences and fluctuations in the variables.

METHODS AND PROCEDURES

Subjects

This dynamic cohort study included observations made over a 14-year period from 1991 to 2005. A total of 7,254 subjects were enrolled in the study, which included 4,328 day workers and 2,926 alternating shift workers, out of a possible 8,251 male workers at a Japanese steel company. No female employees were engaged in alternating shift work. The cohort included subjects who attended annual health examinations during the observation period. The type of job schedule (i.e., shift work or day work) was determined from the payment ledger in May of each year. Workers who were engaged in irregular shift work such as 24-h work and fixed night work were excluded. The shifts were scheduled on a four-team/three-shift plan and clockwise rotation (five day shifts, two rest days, five evening shifts, one rest day, five night shifts and two rest days). The day, evening, and night shifts started at 700, 1500, and 2300 hours, respectively. The study protocol was approved by the Ethics Review Board of the Graduate School of Medicine, Chiba University.

Table 1 The number of subjects and person-years observed for each BMI (kg/m^2) endpoint in the study

	Job schedule type at entry		
	Day	Shift	Total
The number of subjects examined	4,328	2,926	7,254
The number of subjects whose BMI increased by ≥5% (*N* (%))	1,716 (39.6)	1,395 (47.7)	3,111 (42.9)
Total person-years of observation	24,324	18,295	42,619
Incidence rate per 1,000 person-years	70.5	76.3	73.0
Mean observed years per person	5.62	6.25	5.88
The number of subjects whose BMI increased by ≥7.5% (*N* (%))	1,014 (23.4)	843 (28.8)	1,857 (25.6)
Total person-years of observation	28,906	22,590	51,496
Incidence rate per 1,000 person-years	35.1	37.3	36.1
Mean observed years per person	6.68	7.72	7.10
The number of subjects whose BMI increased by ≥10% (*N* (%))	589 (13.6)	516 (17.6)	1,105 (15.2)
Total person-years of observation	31,228	24,888	56,116
Incidence rate per 1,000 person-years	18.9	20.7	19.7
Mean observed years per person	7.22	8.51	7.74

Measurements

At the annual health examination, body weight and height were measured at the same time, in light indoor clothing without shoes, using a fully automatic weighing machine (HWS220; Jokoh, Tokyo, Japan). The time of the health examinations was between 9 AM and 3 PM throughout the study period. Measurements within 30 min of a meal or after heavy physical activity were avoided. The endpoints in the study were defined as increases of either ≥5, ≥7.5, or ≥10% in BMI compared to BMI at entry. Age, BMI measured during the study, drinking and smoking habits, and regular exercise were used as covariates. Drinking, smoking, and habitual exercise were investigated using a self-administered questionnaire in the annual health examination. The workers were classified as either "drinking every day" or "not drinking every day," smokers or nonsmokers, and subjects who exercised regularly or those who did not.

Statistical analysis

In the univariate analysis, the means of age and BMI at entry into the study were calculated and the differences in these between shift workers and day workers were evaluated using *t*-tests. Differences in drinking, smoking, and exercise habits between the two groups were evaluated by the χ^2-test. In the multivariate analysis, a pooled logistic regression analysis was performed to evaluate the effect of shift work on each of the three BMI endpoints measured annually. All the covariates were included simultaneously in the statistical model. Using this method, the derived odds ratios (ORs) for the endpoints were adjusted for the effects of the other covariates. Furthermore, a complementary analysis of percent increase in BMI as a continuous outcome was conducted using multiple regression analysis. In these multivariate analyses, each yearly interval was treated as an independent observation. The analyses were performed with SPSS 15.0J software (SPSS Japan, Tokyo, Japan). A P value < 0.05 was considered statistically significant.

Table 2 Characteristics of the subjects at entry year, grouped according to job schedule type

	Job schedule type at entry				
	Day		Shift		
	M	s.d.	M	s.d.	*P*
Age (years)	36.6	10.9	37.0	9.4	0.086
BMI (kg/m^2)	23.5	2.9	23.3	3.0	0.001
Height (cm)	169.2	6.0	168.8	6.0	0.002
Weight (kg)	67.4	9.5	66.4	9.5	<0.001
	N	%	*N*	%	*P*
Drinking habit (everyday)	1,649	38.1	1,378	47.1	<0.001
Smoking habit (smoker)	2,480	57.3	1,986	67.9	<0.001
Habitual exercise (absence)	1,832	42.3	1,379	47.1	<0.001
Number of subjects	4,328		2,926		

M, mean.

Table 3 The effect of shift work on each endpoint of increased BMI, calculated using pooled logistic regression analyses

	Increase in BMI ≥ 5%		Increase in BMI ≥ 7.5%		Increase in BMI ≥ 10%	
	OR (95%CI)	*P*	OR (95%CI)	*P*	OR (95%CI)	*P*
Job schedule type (shift/day)[a]	1.14 (1.06, 1.22)	0.001	1.12 (1.02, 1.22)	0.022	1.11 (0.99, 1.25)	0.081
Age (years)	0.97 (0.96, 0.97)	<0.001	0.96 (0.96, 0.96)	<0.001	0.96 (0.95, 0.96)	<0.001
Job schedule type (shift/day)[b]	1.14 (1.06–1.23)	0.001	1.13 (1.03–1.24)	0.012	1.13 (1.00–1.28)	0.041
BMI (kg/m^2)	1.02 (1.01–1.04)	0.001	1.04 (1.03–1.06)	<0.001	1.06 (1.04–1.08)	<0.001
Age (years)	0.97 (0.96–0.97)	<0.001	0.96 (0.96–0.97)	<0.001	0.96 (0.95–0.96)	<0.001
Drinking habits (everyday/not everyday)	0.91 (0.84–0.99)	0.028	0.86 (0.78–0.95)	0.004	0.80 (0.70–0.92)	0.001
Smoking habits (smokers/nonsmokers)	1.07 (0.99–1.16)	0.074	1.06 (0.96–1.16)	0.282	1.06 (0.93–1.20)	0.369
Habitual exercise (absence/presence)	1.05 (0.97–1.13)	0.201	1.06 (0.96–1.16)	0.265	1.05 (0.93–1.18)	0.447

Odds ratio (OR): the ratio of the former to the latter was estimated for job schedule type, age, drinking habits, smoking habits, and habitual exercise. 95%CI: 95% confidence interval.
[a]ORs were calculated by an age-adjusted model. [b]ORs were calculated by a fully adjusted model.

Table 4 The effect of shift work on percentage BMI increase relative to BMI at entry

	Unstandardized coefficients (95%CI)	Standardized coefficients	*P*
Job schedule type (shift/day)	0.584 (0.497, 0.671)	0.050	<0.001
BMI (kg/m^2)	0.340 (0.325, 0.355)	0.172	<0.001
Age (years)	–0.064 (–0.069, –0.059)	–0.109	<0.001
Drinking habits (everyday/not everyday)	–0.201 (–0.290, –0.112)	–0.017	<0.001
Smoking habits (smokers/ nonsmokers)	–0.188 (–0.276, –0.099)	–0.016	<0.001
Habitual exercise (absence/ presence)	0.137 (0.050, 0.224)	0.012	0.002

Regression coefficients: the former compared to the latter was estimated for job schedule type, age, drinking habits, smoking habits and habitual exercise. 95%CI: 95% confidence interval.

RESULTS

More than 98% of the workers in the company underwent an annual health examination. The number of subjects and person-years observed are shown in **Table 1**. Of the subjects in the cohort, 3,111 (42.9%) developed a ≥5% increase in BMI, 1,857 (25.6%) a ≥7.5% increase, and 1,105 (15.2%) a ≥10% increase. The incidence rates per 1,000 person-years were 73.0 (≥5% increase in BMI), 36.1 (≥7.5% increase in BMI), and 19.7 (≥10% increase in BMI). The percentage dropouts due to incomplete data were 27, 34, and 38% in the cohorts that had a 5, 7.5, and 10% increase in BMI, respectively. **Table 2** summarizes the characteristics of the shift workers and regular day workers in the cohort. Height, weight, and BMI were all significantly higher in the day workers compared to the shift workers. The percentages of everyday drinking, smoking, and absence of habitual exercise were significantly higher in shift workers compared to day workers.

The results of the pooled logistic regression analysis are shown in **Table 3**. The OR and the 95% confidence intervals

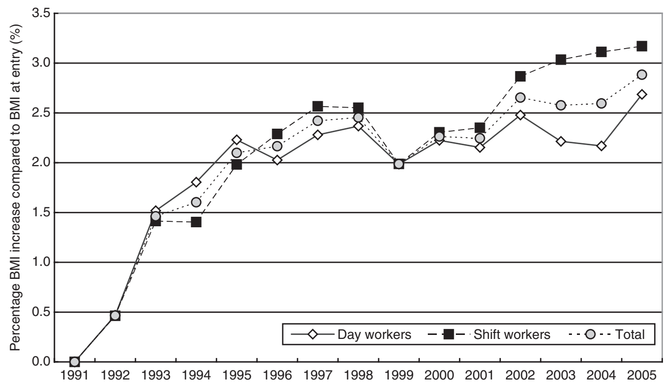

Figure 1 The trend of percentage BMI increase relative to BMI at entry in subjects who were followed for 14 years.

(95%CIs) are summarized according to the BMI endpoints. Using the fully adjusted model, the type of job schedule was associated significantly with all three BMI endpoints (≥5% BMI increase: OR 1.14, 95%CI 1.06–1.23; ≥7.5% BMI increase: OR 1.13, 95%CI 1.03–1.24; ≥10% BMI increase: OR 1.13, 95%CI 1.00–1.28). The annual measurements of BMI were also positively associated with the 5, 7.5, and 10% increases in BMI. In contrast, there was a negative association between age and drinking habits and all three BMI endpoints.

Table 4 shows the result of the multiple regression analysis for percentage BMI increase relative to BMI at entry. Shift workers showed a significant positive regression coefficient. **Figure 1** shows the trend of percentage BMI increase relative to BMI at entry in subjects who were followed for 14 years. Shift workers generally had a greater increase in BMI compared to day workers.

DISCUSSION

In this 14-year cohort study, we examined whether alternating shift work increased BMI. The main finding of this study was that shift work had a significant effect on BMI. A notable feature of the study was that the endpoints were defined as either a 5, 7.5, or 10% increase in BMI relative to the value measured at entry to the study. This is different from other studies in which endpoints were normally defined as a BMI exceeding a certain value, such as 30 kg/m^2. Especially in the longitudinal analysis used in this study, the endpoints in this study prevented bias caused by exclusion of subjects whose BMI at entry exceeded the ordinal definition of the endpoint. Meanwhile, the Expert Committee of World Health Organization proposed a BMI classification with cutoffs of ≥25 kg/m^2 denoting “overweight” and ≥30 kg/m^2 denoting “obesity” (31). On the other hand, the committee noted that weight gain is an important risk factor, as is the distribution of the fat gained. Therefore, weight gain and BMI classification are both good parameters for identifying the condition of harmful fat accumulation in adipose tissue. One other reason was that we took into account the health effects of the same weight change in different people, i.e., a 1 kg increase is more harmful in thin people than in obese people. We therefore used the proportion of weight gain to overcome this effect. Rosengren *et al.* (32) conducted a longitudinal study to assess the risk of death from coronary disease associated with BMI and proportional weight gain in subjects aged between 20 years and middle age. They reported a significantly increased risk of coronary death in subjects with 4–10, 10–15, 15–25, 25–35, and >35% increases in weight, although these significant effects were only observed in subjects with a BMI >30 kg/m^2 (32). Their result therefore supports the validity of the parameters used in our study.

Although the use of a dichotomous outcome measure such as a 5% increase in BMI is useful, it may provide an incomplete picture of what happened to the cohort. Although the mean BMI for the two groups may be identical, because of a greater s.d. in one group, the dichotomous outcomes may be greater in one group. Therefore, it would be useful to provide a complementary analysis of a continuous outcome such as a comparison of gains in weight or BMI between the two groups. As a result of this continuous outcome, BMI increases relative to BMI at entry in shift workers were significantly higher than those in day workers. Accordingly, the concern described above was less likely to have occurred in this study.

In cross-sectional studies on the effect of shift work on worker’s health, there could be a bias caused by subjects dropping out of shift work, resulting in retention of only healthy adaptable persons in the shift workers group. This retention bias is difficult to incorporate into a cross-sectional study design. In such studies, long-term shift workers are considered as “survivors” for the reason that workers with poorer health drop out of shift work more often than healthy workers (33–35). To overcome this bias, it is necessary to carry out a longitudinal study on a cohort of subjects over an extended period of time, and also take into account, the effect of dropouts. Longitudinal studies of this nature, looking at the effects of alternating shift work on the health of workers have seldom been conducted, although as mentioned above, a few studies have reported an increased risk of obesity or weight gain in shift workers. Watari *et al.* (28) carried out a 5-year follow-up study between 1992 and 1997 on 25,312 workers at the time of their annual health check-ups. Pooled logistic regression analyses, similar to those used in this study, were performed with age, working conditions, and lifestyle as the independent variables and the onset of obesity (BMI ≥ 26.4) as the dependent variable adjusted for the time period. These analyses showed no significant association between shift work and the onset of obesity. In that study, subjects on night shift were either engaged on standby or provided a telephone directory enquiry service, with the shifts not being alternated periodically as in this study. This difference in work load at night may explain the different results between our study and this earlier investigation. However, our study demonstrated clearly that alternating shift work affected body weight. Niedhammer *et al.* (29) conducted a longitudinal observational study in nurses that incorporated two 5-year periods between 1980–1985 (n = 363) and 1985–1990 (n = 285). They reported that weight gains exceeding 5 and 7 kg were more frequent in nurses on night work compared to daytime work during the 5-year period 1985–1990. The subjects in this study differed from those in Niedhammer’s study as they were male workers engaged in alternating shift work. Morikawa *et al.* (30) conducted a longitudinal cohort study over a 10-year period in 1,529 Japanese male workers and reported significantly increased BMI in shift workers during the observation period. The effects of potential covariates at baseline were adjusted using analysis of covariance. In this study, we used pooled logistic regression analyses in which each examination interval of 1 year was treated as a mini follow-up study. This pooled logistic regression analysis was equivalent to a Cox time-dependent regression analysis (36). The strength of this method is that the ORs are adjusted for the covariates in the multivariate model, which are in turn, updated at each annual examination (37,38). This method of analysis has been adopted more in recent years (7,8,37–40). Therefore, we believe that the design of our study should improve epidemiological accuracy. The findings of these earlier studies and our study are in general agreement with each other, and establish clearly the effect of shift work on body weight. In addition, none of the subjects in our study switched from alternating shift work to daytime work during the observation period due to the increase in BMI, and therefore it was unlikely that retention bias affected our results. Furthermore, >98% of the workers in the company underwent a health examination every year, ensuring that there was only minimal loss of critical data and no selection bias between compliant and noncompliant subjects.

Several studies (41–46) have evaluated food intake characteristics or nutritional aspects in shift workers. In a comparison between shift and day work, one study (41) observed a lower intake of energy and nutrients in female shift workers because of less frequent and poorer quality meals, although another two studies (42,43) failed to observe these differences. A comparison between work shifts in shift workers showed no significant difference in daily intake of energy (44,46). The total number of eating events per day was significantly higher in night shift workers (45), although these workers had a reduced energy intake during the 8-h night shifts (46). In our study, we did not include the number of meals and food intake per day into the statistical model, as this information was not recorded at the beginning of the observation period. Recently,

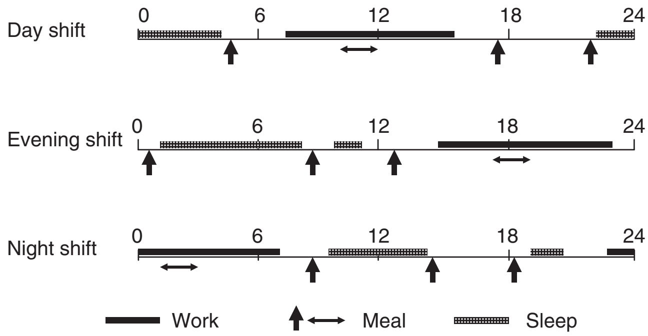

Figure 2 Lifestyle patterns in shift workers on day, evening, and night shifts.

an occupational physician interviewed the shift workers in this company regarding their lifestyle patterns during the day, evening, and night shifts (**Figure 2**). In a representative day shift, the workers got out of bed at 500 hours and ate their first meal, starting work at 700 hours with a second meal at around 1100 hours, finishing work at 1500 hours with a third meal at 1700 hours, before going to bed at 2200 hours. As the time between the third meal and bedtime was relatively long, many day shift workers ate a fourth meal immediately before bedtime. In order to adapt to the evening shift, workers went to bed at 100 hours, got up at 800 hours and ate their first meal, before getting 1 h of sleep from 1000 hours. They then ate their second meal at 1300 hours, starting work at 1500 hours with a third meal at around 1800 hours, before getting off work at 2300 hours and eating their fourth meal at 000 hours. To adapt to the night shift, workers went to bed at 1000 hours, getting up and eating their first meal at 1400 hours. They then stayed awake and ate their second meal at 1800 hours, before getting 1 h of sleep from 1900 hours and start working at 2300 hours, with a third meal at around 200 hours, before getting off work at 700 hours and eating their fourth meal at 900 hours before going to bed. Therefore, shift workers tended to have four meals a day. Two very experienced shift workers were interviewed and they assured us that at least 30% of shift workers close to them have the lifestyle patterns mentioned above. Therefore, the reported lifestyle patterns were not just our assumptions, but rather a speculation based on specific findings. This tendency to eat an additional meal led to weight gain in the shift workers and therefore suggests that future studies in this area should incorporate investigations of lifestyle patterns in the protocol. On the other hand, a preference for some kinds of food may have been another possible confounding factor. In 2002, a detailed questionnaire survey was conducted in the same company (47). A preference for fried food was significantly more frequent in shift workers (46%) than in day workers (42%). However, there was no significant difference in the preference for either sweet or salty food. We therefore suggested that the preference for fried food was another potential factor. On the basis of our results published in 2002 (ref. 47) regarding the types of work, the percentage of onsite workers was 90% for shift workers and 40% for day workers. Of the day workers, 20% were engaged in office work and 22% in research and technical work. In this company, onsite workers are engaged in activities related to steel production and equipment maintenance. Onsite workers usually monitor and operate the production process remotely in a safe and comfortable operations room, without the demand for heavy physical labor. Occasionally these workers enter the production site to carry out equipment maintenance while the production process is suspended. Therefore, work type was not a major confounding factor in our study. On the other hand, socioeconomic status such as income level, marital status, and educational level may have influenced the results. Marital status and living arrangements did not differ between day workers and shift workers. For example, 79% of the day workers were married compared to 74% of the shift workers, and 87% of day workers lived with their family compared to 86% of shift workers (47). The economic status of the shift workers was generally good because they received shift differential pay provided by this large Japanese steel company. The educational levels were very similar between the day and shift workers, with most workers being high school graduates. Very few university graduates were engaged in daytime work. Therefore, we consider that socioeconomic status was not a major confounding factor in this study. Sleep duration has been implicated recently as an independent risk factor for weight gain (48,49). Although a simple comparison between shift and day workers was inappropriate due to the underlying qualitative differences in sleep patterns, mean sleep duration was similar in the two groups (shift workers, 6.6 h/day vs. day workers 6.7 h/day in 2002).

In this study, drinking habits and older age decreased the risk of increased BMI. Drinking habits are usually assumed to be a risk factor for obesity as alcohol itself is high in calories and drinkers also tend to eat high-calorie meals. The paradox between increased alcohol-induced energy intake and a lack of correlation between alcohol intake and body weight has been reported previously (50). Suter (51) pointed out that the relationship between weight and alcohol shows no consistent patterns, with some epidemiologic studies reporting a positive association, others a negative association, and others no relationship at all. However, recent longitudinal studies in the United States demonstrated a lower OR for obesity in current drinkers compared to nondrinkers (20,52), whereas a study in Japanese male workers found that drinking alcohol more than five times per week decreased the risk of developing obesity compared to abstinence (28). As our results are consistent with these findings, the reliability of our study was not reduced by our finding of a paradoxical relationship between alcohol and weight gain.

In this study, a negative effect of age was observed for each endpoint of increased BMI. Regarding the effect of age, there is a report of a cross-sectional annual nationwide survey carried out in Japan during 1976–1995 by the National Health and Nutrition Survey, which included 91,983 men and 120,822 women from the Japanese general population (21). During 1981–1985, 11.8% of the subjects in their 20 s were overweight (BMI ≥ 25). After 10 years (1991–1995), the prevalence of overweight subjects in that generation had increased by 13.3–25.1%.

In contrast, the prevalence of overweight subjects in their 50s during 1981–1985 was 21.5% which then increased by only 1.9–23.4% after 10 years (21). Thus, as a general trend, the prevalence of overweight subjects increased more in younger men than in older men in Japan during the period of this study. On the basis of this trend with age, the lower variability in body weight found in older subjects may be the reason for the negative effect of age on weight gain observed in our study.

In summary, our study revealed that alternating shift work is an independent risk factor for weight gain in male Japanese workers. The company under study adopted an alternating shift work schedule that is representative in well-ordered Japanese factories. This schedule involved a four-team/three-shift system with clockwise rotation. Therefore, efficient health screening and regular checkups combined with support in controlling unhealthy lifestyle factors has the potential to be of considerable benefit in maintaining the health of Japanese shift workers.

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DISCLOSURE

The authors declared no conflict of interest.

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