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Retrospective cohort study of the risk of obesity among shift workers: findings from the Industry-based Shift Workers' Health study, Japan

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ABSTRACT

Objectives The authors investigated the effect of shift working on the risk of obesity using data from the Industry-based Shift Workers' Health (IbSH) study, a retrospective cohort study based on a health care database system belonging to a manufacturing corporation in Japan.

Methods The study database contains data on annual health check-ups and work schedules for every worker in the corporation in Japan since 1981. Study subjects consisted of 9912 male employees (8892 daytime workers and 920 rotating three-shift workers; mean age at first check-up was 23.7 years) whose work schedules were consistent during the follow-up period. Obesity was defined as a body mass index ≥25.0.

Results 3319 cases of obesity were recorded over the 27.5 years of retrospective follow-up. Kaplan–Meier survival analysis visually demonstrated an increased risk of obesity among shift workers. The risk becomes particularly obvious after 10 years of follow-up. Cox proportional-hazards model analysis revealed a significantly increased risk among shift workers (RR 1.14, 95% CI 1.01 to 1.28).

Conclusion The risk of obesity among male shift workers was visually and statistically demonstrated.

What this paper adds

- Epidemiological studies on shift work face difficulties regarding work schedule follow-up, potential significant result bias due to the healthy worker effect, and confounding by socioeconomic factors.
- To overcome these issues, we established a new retrospective cohort study with unique strengths.
- Study subjects consisted of 8892 daytime workers and 920 rotating three-shift workers in one company, whose work schedules were consistent during the follow-up period.
- Kaplan–Meier survival analysis demonstrated a risk of obesity among shift workers which became apparent after 10 years of follow-up.
- The results suggest occupational health practitioners should take account of a subject's work schedule when giving health guidance.

Shift work is widely practised in workplaces which require around-the-clock operations. In the USA and Europe, for example, some 15–20% of workers are estimated to work on shift schedules.[1] Previous studies have reported that shift workers, whose lifestyles are disrupted due to work scheduling, are at high risk of developing disturbed sleep, gastrointestinal disturbances, hypertension, hypercholesterolaemia and obesity.[2–6] Obesity is known to contribute to cardiovascular disease, type 2 diabetes and several cancers, and recent studies have shown that obesity in adulthood is associated with an approximately 7-year decrease in life expectancy, a magnitude of loss similar to that associated with smoking.[7 8] The risk of obesity among shift workers is a public health concern and evaluation of this risk is necessary.

However, despite repeated examination of the issue, results from studies conducted thus far have been relatively inconclusive, with both positive and negative relationships being noted.[4 6 9–13] One limitation to determining any causal relationships is lack of consistency; inconsistencies in results may reflect common issues facing epidemiological studies regarding shift work. Several major concerns further hamper accurate assessment of any associations, namely difficulty in work schedule follow-up, potential significant result bias due to the healthy worker effect, and confounding by socioeconomic factors. With regard to work schedule follow-up, an employee's schedule may change over time, thereby hampering long-term precise follow-up of the work schedule. With regard to bias associated with the healthy worker effect, healthy daytime workers may be selected as shift workers to give un-healthy shift workers the chance to move to daytime work, which may lead to selection bias and underestimation of the risks. With regard to confounding factors, socioeconomic differences in, for example, educational level or domestic finances, between shift workers and daytime workers may confound the results.

To tackle these issues, we established a new retrospective cohort study, the Industry-based Shift Workers' Health study, and investigated the effect of rotating shift work on the risk of obesity using a reliable dataset.

MATERIALS AND METHODS

The Industry-based Shift Workers' Health (IbSH) study is an industry-based epidemiological study based on a healthcare database system belonging to a manufacturing corporation in Japan. The corporation is a manufacturer of innovative products based on chemistry and material sciences. In this particular corporation, the results of annual health check-ups (including body mass index (BMI)) and the work schedule of every worker have been recorded since 1981. At present, more than 25 700 workers are registered, and the database is still being updated. Using this information bank, data regarding the effects of long-term shift work can be easily and accurately obtained. The shift system in place consisted of four teams working three continuous counterclockwise shifts.

In January 2009, records of work schedules and health check-ups for 20 529 male workers were extracted from the database. In order to isolate the appropriate data for our analysis, the subject group was restricted to 13 013 male workers aged less than 30 years at their first health examination. The subjects were further limited to the 11 645 individuals who were not obese (BMI<25) at their first health examination. Finally, subjects were restricted to 9912 workers whose work schedules were consistent during the follow-up period (mean (SD) age 23.7 (2.7) years; mean (SD) BMI 21.2 (1.8)). Of these 9912 workers, 8892 were permanent daytime workers and 920 were permanent rotating three-shift workers. A case of obesity was defined as a participant with a BMI≥25.0 according to the recommendation of Japan Society for the Study of Obesity.[14] The criterion was reported to provide the best combination of sensitivity and specificity for identifying subjects with complications such as hyperglycaemia, dyslipidaemia and hypertension and found to be an appropriate index of obesity for research purposes among Japanese subjects.[14 15] During the 27.5 years of follow-up (135 399 person-years in total; mean follow-up period 13.6 years), 3319 cases of obesity were identified.

From the earliest available self-administered questionnaire for the annual health check-up for each employee, we acquired information on the following factors: smoking habit (never smoker, current smoker, ex-smoker), alcohol consumption (non-drinker, drinker), and frequency of physical activity during leisure time (<3 days/week, ≥3 days/week).

Kaplan–Meier survival curves and the log-rank test were used to compare the risk of developing obesity between rotating shift workers and daytime workers (figure 1). Relative risks (RRs) were estimated using the Cox proportional-hazard model. In this analysis, RRs were adjusted for age only, and for age, smoking habit, alcohol consumption and frequency of physical activity during leisure time. Missing values of adjusting variables were treated as an additional category for this analysis. To display quantitative change in the BMI of subjects, descriptive analysis was additionally performed among the study subjects. For this analysis, subjects were not excluded from the analysis even after the date they became obese (BMI≥25.0) and changes in work schedule after that date were not taken into account. Calculations were performed with Stata v. 10.0 and SPSS v. 12.0.

Approval

This study was approved by the Ethics Committee for Medical Care and Research at the University of Occupational and Environmental Health, Japan.

RESULTS

Table 1 describes baseline patient characteristics according to the type of work schedule. Of the 9912 male workers, 8992 (90.7%) were permanent daytime workers and 920 (9.3%) were permanent rotating three-shift workers. Shift workers were slightly younger than daytime workers (mean age 22.2 vs 23.8 years, respectively). No difference in mean BMI was noted between the two types of workers at the first health check-up. With regard to lifestyle factors, shift workers showed a higher prevalence of current smoking than daytime workers (58.8% vs 47.6%, respectively) and a lower prevalence of current drinking (65.2% vs 75.2%, respectively). With regard to leisure-time physical activity on ≥3 days/week, no differences were observed between the two groups (58.3% vs 56.2%).

Figure 1 shows the Kaplan–Meier survival curves for obesity, visually demonstrating the significant between-group difference in survival rate (log-rank test; p=0.005). The risk becomes particularly obvious after 10 years of follow-up.

Table 2 shows the results of analysis with the Cox proportional-hazards model. Annual incidence ratios for obesity (incidences/person-years) were 2.41% for daytime workers and 2.78% for rotating shift workers (2.45% overall), that is to say the crude RR was significantly higher among rotating shift workers than among daytime workers (RR 1.16, 95% CI 1.05 to 1.29). Results were not significantly altered even following adjustment for age alone (RR 1.17, 95% CI 1.04 to 1.31), or age, smoking habit, alcohol consumption and physical activity during leisure time (RR 1.14, 95% CI 1.01 to 1.28). Controlling variable 'current smoker' revealed increased RR for obesity (RR 1.13, 95% CI 1.04 to 1.22), while 'ex-smoker' and 'leisure-time physical activity (≥3 days/week)' revealed decreased RR (RR 0.89, 95% CI 0.80 to 0.99; RR 0.93, 95% CI 0.83 to 1.00, respectively). 'Current drinker' was not associated with risk (RR 1.00, 95% CI 0.92 to 1.08).

Table 3 shows quantitative change in the BMI of the subjects according to work schedules. Mean BMI gradually increased among both groups during the follow-up period. The maximum increase in mean BMI since the first health check-ups was 2.30 kg/m^2 among daytime workers at 27 years of follow-up and 2.85 kg/m^2 among rotating shift workers at 26 years of follow-up. The increase in BMI was greater among daytime workers for the first 5 years, however, after 6 years of follow-up shift workers had a greater increase in BMI compared to daytime workers. After 9 years of follow-up, the mean BMI of shift workers exceeded that of daytime workers (22.59 vs 22.56 kg/m^2, respectively). The maximum difference in increased BMI between the work schedules was 0.58 kg/m^2 which was observed at 26 years of follow-up.

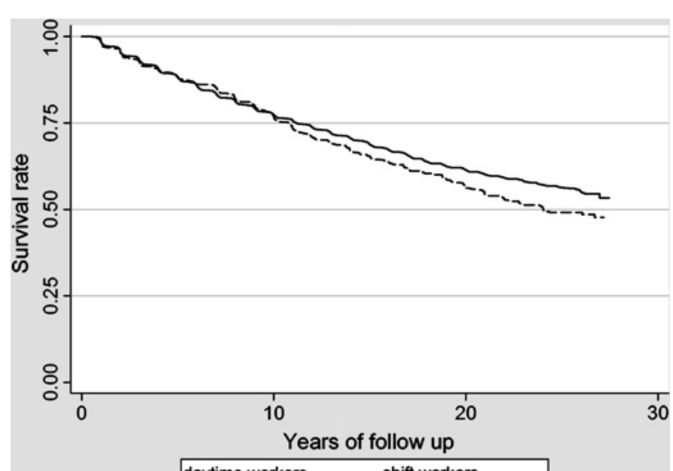

Figure 1 Kaplan–Meier survival curves for obesity among 9912 male workers according to type of work schedule.

Table 1 Baseline characteristics of 9912 male workers according to type of work schedule

	Work schedule		
	Day time	Rotating shift	p Value
Number of subjects	8992 (90.7%)	920 (9.3%)	
Mean years of follow-up	13.5	15.7	
Person-years	120947	14452	
Number of cases of obesity	2917	402	
Mean (SD) age	23.8 (2.4)	22.2 (4.0)	<0.001*
Mean (SD) BMI	21.2 (1.8)	21.1 (1.9)	0.097*
Lifestyle factors			
Smoking (%)			<0.001†
Current smoker	47.6	58.8	
Never smoker	34.0	22.8	
Ex-smoker	16.4	15.1	
Missing	1.9	3.3	
Alcohol consumption (%)			<0.001†
Current drinker	75.2	65.2	
Non-drinker	22.9	31.5	
Missing	1.9	3.3	
Leisure-time physical activity (%)			<0.001†
≥3 days/week	56.2	58.3	
<3 days/week	34.1	38.5	
Missing	9.7	3.3	

*p Values were derived from the Student t test.
†p Values were derived from the χ^2 test.

DISCUSSION

The Kaplan–Meier survival curves of 9912 workers with permanent work schedules showed an increased risk of obesity among rotating shift workers after a follow-up period of 27.5 years (mean follow-up period 13.6 years). RR obtained by Cox proportional-hazards model analysis revealed significantly increased risk among shift workers even after adjustment for covariates including age, smoking, alcohol consumption and physical activity during leisure time. Quantitatively, shift workers revealed a greater increase in BMI after 6 years of follow-up compared to daytime workers and the maximum difference in increased BMI between the work schedules was 0.58 kg/m^2 during the follow-up period.

Our study's design is superior to that of previous studies in several aspects. First, we were able to obtain very good quality exposure information. Long-term (up to 27.5 years) follow-up information for work schedules was available, and the validity and reliability of the exposure information was high, with instances of misclassification found to be rare. Further, BMI data were obtained via the company's annual health check-ups, and thus were also of good quality. Second, the cohort study design may have reduced the influence of the healthy worker effect to some extent. In cross-sectional studies, controlling for the healthy worker effect is theoretically difficult; subjects who developed ill-health while working shifts and were moved to daytime work were probably treated as daytime workers in analysis, even if the illness was associated with shift work. Such misclassification would result in underestimation of the risk, but was avoided in this study. Third, since all study subjects belonged to the same company, socio-economic differences are believed to have had relatively little effect on the results. For example, all subjects had very stable employment conditions and used the same occupational health services. The effect of a socioeconomic differences may therefore be relatively small in the present study compared to studies conducted among several companies or in the general population. We believe that these unique strengths contributed significantly to the reliability of our results.

With regard to the observed relationship between shift work and risk of obesity, a previous study has cited decreased opportunities for physical activity and participation in sports among shift workers.[16] Among subjects in the present study, however, no material difference was observed in physical activity during leisure time between the two work schedule groups. In addition, at this particular company, physical activity during work time was presumed to be higher among shift workers than daytime workers. Further, adjustment by physical activity did not alter the results of survival analysis. Taking these findings into account, we found no relationship between lack of physical activity among shift workers and obesity risk. Eating habits were not evaluated in the present study, although previous studies have suggested that shift work does not alter total energy intake per se, but rather reduces meal frequency and increases snacking during the night shift.[16] Omitting breakfast or eating at night has been reported to contribute to increased risk of obesity.[17] Taken together, these findings suggest that disturbed meal schedules rather than total energy intake may play an important role in the risk of developing obesity.

In this study, 'late onset' of the obesity risk among shift workers was found. After 6 years of follow-up, shift workers

Table 2 Relative risk of obesity in shift workers

			Crude			Age-adjusted			Multivariate		
	Person-years	Number of cases	RR	95% CI	p Value	RR*	95% CI	p Value	RR†	95% CI	p Value
Work schedule											
Day time work	120947	2917	1.0			1.0			1.0		
Rotating shift work	14452	402	1.16	(1.05 to 1.29)	0.005	1.17	(1.04 to 1.31)	0.008	1.14	(1.01 to 1.28)	0.029
Control variable for lifestyle factors											
Smoking											
Never smoker									1.0		
Current smoker									1.13	(1.04 to 1.22)	0.003
Ex-smoker									0.89	(0.80 to 0.99)	0.035
Alcohol consumption											
Non-drinker									1.0		
Current drinker									1.00	(0.92 to 1.08)	0.959
Leisure-time physical activity											
<3 days/week									1.0		
≥3 days/week									0.93	(0.83 to 1.00)	0.043

*Relative risk adjusted by age only.
†Relative risk adjusted by age, smoking, drinking and physical activity during leisure time.

revealed a greater increase in BMI compared to daytime workers (table 3). It was also shown on the survival curves in figure 1 that the risk becomes particularly obvious after about 10 years of follow-up. The reasons for these findings are unclear, although it was reported that obesity becomes more prevalent among Japanese men in their 30s.[18] In this study, the mean age of subjects after 6 years of follow-up was 29.7 years. Shift work conditions might somehow accelerate the change in BMI at that age. Also, most subjects probably marry in their 30s, and shift workers may be more likely late at night to eat meals prepared by their wives.

In recent years, debates regarding the relationship between shift work and the risk of obesity have focused on genetics. Mice with a mutant Clock gene showed an attenuated feeding rhythm and became hyperphagic, developing obesity and metabolic syndrome.[19] In humans, genetic expression of the mutant Clock gene is known to vary with interventions such as sleep therapy.[20] These findings suggest that shift work may contribute to gene expression disorders, and disturbed expression of the Clock gene among shift workers may be a factor contributing to obesity.

To communicate the risks, occupational health practitioners should take into account a subject's work schedule when conducting health check-ups. Future occupational health research should prioritise the development of methods to teaching shift workers about healthy eating, exercise and sleeping habits. Additionally, a shift work schedule less burdensome for workers is also needed. Few intervention trials have been conducted regarding these topics, and to our knowledge, no reference model has been established.[16 21] Further research into these topics is therefore of the utmost importance.

Study limitations

Several limitation to the present study warrant mention. First, we collected no information regarding dietary habits or patterns, and thus the effect of diet could not be evaluated. Detailed quantitative information on physical activity was also not available. Second, the database did not provide information regarding job type or job level. However, it seemed likely that shift workers were engaged more in production/maintenance work, while office workers, administrators and managers would be chiefly day workers. Physical activity during work might be higher among shift workers, and lack of that information might result in underestimation of the risk. Differences in job levels between work schedules might also confound the result, since an association between socioeconomic status and obesity was suggested.[22–24] The direction of the association, however, has been reported variously and effects of those factors on the results are difficult to presume. Third, some selection bias was unavoidable, as we excluded those subjects who had their work schedules rearranged. Workers who moved from shift work to daytime work due to sift work related health problems were excluded from the analysis, so study subjects may have been limited to the 'healthy survivors'. However in that case, the risk would have been underestimated and the bias would not have affected our conclusions. Fourth, work schedules were recorded at the time of annual health check-ups, and therefore any short-term rearrangements in the work schedule were ignored.

Table 3 Quantitative change in body mass index (BMI) according to work schedule

Years of follow-up	Number of subjects	Work schedule: Daytime work — Mean BMI	(Increase*)	Rotating shift work — Mean BMI	(Increase*)	Difference†
0	9912	21.22	–	21.11	–	–
1	9439	21.36	(0.15)	21.21	(0.11)	−0.04
2	9286	21.55	(0.33)	21.36	(0.26)	−0.07
3	9036	21.71	(0.50)	21.53	(0.43)	−0.07
4	8908	21.86	(0.65)	21.71	(0.61)	−0.04
5	8804	22.04	(0.83)	21.91	(0.81)	−0.02
6	8570	22.19	(0.98)	22.12	(1.02)	0.04
7	8396	22.32	(1.12)	22.24	(1.14)	0.03
8	8212	22.43	(1.23)	22.41	(1.31)	0.08
9	8028	22.56	(1.36)	22.59	(1.49)	0.13
10	7784	22.65	(1.45)	22.80	(1.70)	0.24
11	7524	22.75	(1.55)	22.95	(1.85)	0.30
12	7530	22.83	(1.63)	23.11	(2.01)	0.38
13	7329	22.92	(1.72)	23.14	(2.04)	0.32
14	7073	23.01	(1.81)	23.27	(2.17)	0.36
15	6655	23.10	(1.90)	23.37	(2.27)	0.37
16	6069	23.14	(1.94)	23.39	(2.29)	0.35
17	5477	23.19	(1.99)	23.48	(2.38)	0.39
18	5018	23.24	(2.04)	23.47	(2.37)	0.33
19	4622	23.30	(2.10)	23.56	(2.46)	0.36
20	4342	23.32	(2.12)	23.64	(2.54)	0.41
21	3914	23.39	(2.19)	23.70	(2.60)	0.41
22	3405	23.42	(2.22)	23.72	(2.62)	0.40
23	3079	23.43	(2.23)	23.86	(2.76)	0.52
24	2830	23.47	(2.27)	23.91	(2.81)	0.54
25	2318	23.48	(2.28)	23.89	(2.79)	0.51
26	1474	23.47	(2.27)	23.95	(2.85)	0.58
27	345	23.50	(2.30)	23.82	(2.72)	0.42

*Increase in BMI from baseline.
†Difference in increased BMI between work schedules.

However, we feel any potential effect of this oversight was limited, given the long period of follow-up.

CONCLUSION

Examination of the records of 8892 permanent daytime workers and 920 permanent rotating three-shift workers in one company found an increased risk of obesity among shift workers after a maximum follow-up of 27.5 years. Future occupational health research should prioritise the development of methods of teaching shift workers about healthy eating, exercise and sleeping habits.

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Competing interests None.

Ethics approval This study was conducted with the approval of the Ethics Committee for Medical Care and Research at The University of Occupational and Environmental Health, Japan.

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