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Effect of shift work on body mass index and metabolic parameters

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Objectives The aim of this cohort study was to investigate the effects of shift work on changes in parameters related to metabolic disturbances.

Methods The study population included 1529 male blue-collar workers, aged 19–49 years at baseline, working in a sash and zipper factory in Japan. The participants were divided into four groups according to the work schedule at baseline, the end point being workers doing fixed daytime work in both years (day–day), workers who changed from shift work to fixed daytime work (shift–day), workers who changed from fixed daytime work to shift work (day–shift), and workers doing shift work in both years (shift–shift). The changes in body mass index (BMI), blood pressure, serum cholesterol, and glycosylated hemoglobin A1c over a period of 10 years were compared among the groups by work schedule.

Results The age-adjusted mean increase in BMI was 1.03 kg/m² for the day–shift workers, and it was significantly larger than that of the day–day workers and shift–day workers. The shift–shift workers showed a significantly larger increase in BMI than the day–day workers. These tendencies remained after adjustment for age and all other confounding factors, such as BMI, smoking, drinking, and leisure-time physical activity at baseline. The increase in total cholesterol tended to be higher among the shift–shift workers and the day–shift workers, but there were no significant differences. Blood pressure and hemoglobin A1c did not differ among the four groups.

Conclusions Shift work is considered to be a risk factor for excess weight. However, no significant difference in the biomarkers was found between daytime workers and shift workers.

Key terms blood pressure; cholesterol; cohort study; glycosylated hemoglobin.

Shift work has been associated with an increased risk of cardiovascular disease (CVD) (1–3). Four pathways—mismatch of circadian rhythms, social disruption, behavioral changes, and changes in biomarkers—are considered to be the factors that predispose shift workers to CVD (1). The pathway of changes in biomarkers has been investigated in many studies. However, because of the limited number of longitudinal designs, this pathway remains unclear (1). Overall, among the studies of the relationship of shift work to the metabolism of lipids, glucose tolerance, and obesity, negative studies are numerically superior (1). Recently, more cross-sectional studies have revealed that shift workers have a higher

prevalence or a higher level of biomarkers of CVD (4–9). The results of short-term prospective studies were inconsistent (10, 11). Both a decrease and an increase in biomarkers related to CVD were reported. Intervention studies indicated that introducing a better shift schedule into the workplace improved biomarkers (12) or introducing a worse shift schedule caused weight gain (13). There have been several long-term follow-up studies. Increased risks of obesity and weight gain among shift workers have been reported in a few studies (14–16). We reported on increased risk of the onset of diabetes mellitus and hypertension among shift workers in two cohort studies (17, 18). To reach conclusions on the

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health effects of shift work, we need more long-term prospective studies.

The aim of this study was to investigate the effects of shift work on changes in parameters related to metabolic disturbances, determined by a 10-year follow-up study. As factors related to changes in biomarkers, behavioral factors such as dietary intake, physical activity, alcohol intake, and smoking were also investigated.

Study population and methods

Study population

The cohort consisted of blue-collar workers ranging from 18 to 49 years of age in a Japanese zipper and sash factory. We followed the participants from 1993 to 2003 and investigated the changes in body mass index (BMI), blood pressure, serum cholesterol, and glycosylated hemoglobin A1c (HbA1c). The target population numbered 1807, and 1711 persons (94.7%) could be followed to the end point. Among them, 182 changed to white-collar work during the 10 years; therefore, 1529 persons were used for the longitudinal analysis. A comparison of baseline data between the 1711 persons who could be followed and the 96 dropouts did not show any significant differences in the parameters evaluated.

Occupations

The work schedules were obtained from questionnaires administered in 1993 and 2003. The participants were classified into the following four groups according to the work schedule in 1993 and 2003: (i) day–day workers, those who did fixed daytime work in both 1993 and 2003, (ii) shift–day workers, those who did shift work in 1993 and transferred to fixed daytime work during the observation period, (iii) day–shift workers, those

who did fixed daytime work in 1993 and transferred to shift work during the observational period, and (iv) shift–shift workers, those who did shift work in both 1993 and 2003. The number of participants in each group is shown in table 1. The mean age of the shift–shift workers was the lowest among the four groups. The self-reported length of shift work up to 2003 was the longest for the shift–shift workers [19.0 (SD 8.2) years], followed by the shift–day workers [13.5 (SD 9.2) years], the day–shift workers [10.1 (SD 7.9) years], and the day–day workers [3.9 (SD 5.7) years]. Of the shift workers, 72.5% did rotating three-shift work, and the rest did rotating two-shift work. The three-shift workers rotated counterclockwise. Two-thirds of them were engaged in a noncontinuous shift system (5 day shifts, 5 night shifts, and 5 evening shifts), and one-third worked on a continuous-shift system (3- or 4-day shifts, 3- or 4-night shifts, and 3- or 4-evening shifts, with 1 rest day between successive shifts). Both rotating three-shift systems changed shifts at 0800, 1630, and 0015 or 0630, 1300, and 2130. Certain jobs, such as those involving the operation of machines that melt, heat, mix, or cast, were routinely performed by the three-shift workers, while jobs involving processing or constructing aluminum products were done by fixed daytime workers or two-shift workers.

Data collection

The anthropometrical data and biomarkers were obtained in 1993 and 2003. Body mass index (BMI) was calculated as weight (kilograms) divided by height squared (meters²). Blood pressure was measured in a sitting position after rest for 5 minutes. Serum total cholesterol and HbA1c were measured at the time of the health survey in both 1993 and 2003. Blood was not always taken as fasting samples. Health-related behavior was also recorded in 1993 and 2003 on questionnaires.

Table 1. Baseline characteristics of the groups of work schedule at baseline (1993) and the end point (2003). (BP = blood pressure, HbA1c = glycosylated hemoglobin A1c)

Work schedule in 1993 and 2003	Age (years)		Body mass index (kg/m ²)		Systolic blood pressure (mm Hg)		Diastolic blood pressure (mm Hg)		Total cholesterol (mmol/l)		HbA1c (%)		Current smoker (%)	Exercise ^a (%)	Alcohol consumption ^b (%)
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Day → day (N=712)	36.4	8.2	22.39	2.76	118.3	13.4	71.6	10.2	5.07	0.86	4.98	0.57	67.5	66.6	41.9
Shift → day (N=210)	36.0	8.0	22.79	2.66	117.0	12.4	69.9	10.2	5.03	0.89	4.95	0.42	59.9	70.8	46.8
Day → shift (N=173)	36.2	8.2	22.96	2.84	117.7	11.6	70.5	9.6	4.99	0.97	4.89	0.42	62.2	66.1	40.1
Shift → shift (N=434)	33.5	8.6	22.38	2.99	119.6	13.0	70.5	10.4	5.03	0.90	4.91	0.36	64.1	67.9	44.0
Total (N=1529)	35.5	8.4	22.51	2.83	118.4	13.0	70.9	10.2	5.04	0.89	4.95	0.48	64.9	67.5	42.3

^a Less than once a week.

^b Almost every day.

Nutritional intake was evaluated in 2003 using a self-administered diet history questionnaire (19). The total energy intake, the proportion of energy intake from protein, fat, and carbohydrates, and alcohol intake were calculated. The total energy expenditure during an entire day was evaluated in 2003 using a self-administered physical-activity questionnaire.

Table 1 shows the baseline characteristics by occupational group.

Statistics

The relationships between the change in parameters over 10 years, work schedule, and other confounding factors were analyzed using a multiple linear regression. The means of the changes in the parameters over 10 years after adjustment for age and other confounding factors were calculated in an analysis of covariance. The nutritional intake, energy expenditure, and prevalence of smokers and habitual drinkers in 2003 were compared among the groups using a cross-sectional analysis. Total calorie intake was compared among the occupational groups after adjustment for height in an analysis of covariance. The software package used for the analysis was SPSS, version 11.0 (SPSS Inc, Chicago IL, USA).

Results

Table 2 shows the relationships between changes in the parameters over a period of 10 years and the history of the work schedule by multiple linear regression analysis. Transferring from fixed daytime work to shift work (day-shift) and continuing shift work (shift-shift) were recognized as risk factors for an increase in BMI.

Continuing shift work (shift-shift) tended to increase total cholesterol ($P=0.051$). We could not find any significant relationship between the work schedules and HbA1c or blood pressure.

Table 3 shows the changes in each parameter over the 10-year period after adjustment for age and other confounding factors. The age-adjusted mean increase in BMI was the largest among the day-shift workers, followed by the shift-shift workers, the shift-day workers, and the day-day workers. The age-adjusted mean increase in BMI of the day-shift workers was 1.03 kg/m^2 , significantly larger than that of the day-day workers and the shift-day workers. The shift-shift workers showed a significantly larger increase in BMI than the day-day workers. These statistical significances remained after adjustment for age and all other confounding factors, such as BMI, smoking, drinking, and leisure-time physical activity. The increase in total cholesterol tended to be higher among the shift-shift workers and day-shift workers, but the differences were not significant. Systolic blood pressure, diastolic blood pressure, and HbA1c did not differ among the groups.

Table 4 shows the mean nutritional intake and energy expenditure during an entire day and the prevalence of smoking by occupational group. The mean total calorie intake was calculated after adjustment for height because height is a major relevant factor of the necessary amount of total calories. There was a significant difference in total calorie intake among the groups. The calorie intake of the day-day workers was the least among the four groups, and the difference was statistically significant. However, the proportions of calories from protein, fat, and carbohydrates did not differ significantly among the groups. The prevalence of smoking, the upper quartile of alcohol intake, and energy expenditure did not differ among the groups.

Table 2. Relationship between changes in the parameters over a period of 10 years and work schedule and baseline characteristics in a multiple linear regression analysis. (HbA1c = glycosylated hemoglobin A1c, Std β = standardized beta, NS = no statistical significance)

Factors	Body mass index		Systolic blood pressure		Diastolic blood pressure		Total cholesterol		HbA1c	
	Std β	P-value	Std β	P-value	Std β	P-value	Std β	P-value	Std β	P-value
Age (year)	-0.143	<0.00	0.237	<0.001	0.106	<0.001	-0.170	<0.001	0.048	0.077
Body mass index (kg/m^2)	0.369	<0.001	0.193	<0.001	0.119	<0.001	0.075	0.004	0.116	<0.001
Smoking (yes versus no)	0.057	0.019	-0.019	NS	0.032	NS	0.050	NS	0.058	0.030
Leisure-time physical activity (<1/week versus ≥ 1 /week)	-0.020	NS	0.034	NS	0.033	NS	0.053	0.042	-0.008	NS
Drinking (everyday versus other)	-0.023	NS	NS	NS	0.128	<0.001	0.017	NS	-0.028	NS
Work schedule ^a										
Shift-day versus day-day	-0.014	NS	-0.028	NS	0.039	NS	0.026	NS	-0.010	NS
Day-shift versus day-day	0.052	0.040	-0.034	NS	0.006	NS	0.037	NS	-0.006	NS
Shift-shift versus day-day	0.061	0.019	-0.019	NS	0.004	NS	0.055	0.051	0.033	NS

^a Day-day, shift-day, day-shift, shift-shift, categorized by work schedule in 1993 and 2003.

Table 3. Comparison between the increase in the parameters over a 10-year period among the workers grouped by work schedule in an analysis of covariance. (NS = no statistical significance)

	Work schedule in 1993 and 2003								
	Day → day		Shift → day		Day → shift		Shift → shift		P-value ^a
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Adjusted for age ^b									
Body mass index (kg/m ²)	0.63	0.06	0.63	0.11	1.03	0.12 ^{c, d}	0.88	0.07 ^c	0.002
Systolic blood pressure (mmHg)	3.4	0.6	3.9	1.1	2.9	1.2	2.5	0.8	NS
Diastolic blood pressure (mmHg)	5.5	0.4	6.9	0.8	6.0	0.9	5.4	0.6	NS
Total cholesterol (mmol/l)	0.255	0.028	0.307	0.052	0.350	0.057	0.338	0.036	NS
Glycosylated hemoglobin A1c (%)	0.14	0.02	0.09	0.04	0.18	0.04	0.14	0.03	NS
Adjusted for confounding factors ^e									
Body mass index (kg/m ²)	0.62	0.06	0.64	0.11	1.08	0.12 ^{c, d}	0.89	0.07 ^c	0.001
Systolic blood pressure (mmHg)	3.5	0.6	3.5	1.1	2.6	1.2	2.6	0.8	NS
Diastolic blood pressure (mmHg)	5.4	0.4	6.8	0.8	5.9	0.9	5.6	0.6	NS
Total cholesterol (mmol/l)	0.249	0.029	0.322	0.053	0.366	0.058	0.349	0.037	0.098
Glycosylated hemoglobin A1c (%)	0.13	0.02	0.09	0.04	0.13	0.04	0.18	0.03	NS

^a P-value: statistical significance between groups.^b Estimated mean adjusted for age.^c Statistical significance (P<0.05) compared with "day-day" workers.^d Statistical significance (P<0.05) compared with "shift-day" workers.^e Estimated mean adjusted for age, body mass index, smoking, alcohol consumption, and leisure-time physical activity at baseline.**Table 4.** Comparison of nutritional intake, energy consumption, and percentage of smokers and habitual drinkers at the end point (2003) among the workers when grouped by work schedule.

Work schedule in 1993 and 2003	Nutritional intake								Energy expenditure (metz)	Consumers of alcohol ^b	Current smokers	
	Total calorie (kcal/day) ^a		Calorie from protein (%)		Calorie from fat (%)		Calorie from carbohydrate (%)					
	Mean	SD	Mean	SD	Mean	SD	Mean	SD				
Day → day	2117	27	11.0	2.1	19.9	6.4	60.1	8.7	40.3	0.3	23.9	57.3
Shift → day	2229 ^c	49	10.8	1.8	20.6	6.5	59.9	8.5	40.2	0.5	24.1	47.2
Day → shift	2252 ^c	34	11.0	2.2	20.8	6.7	59.4	8.6	40.7	0.3	24.4	54.9
Shift → shift	2362 ^c	56	11.1	2.0	20.0	7.4	59.8	9.6	41.0	0.5	32.2	52.6

^a Estimated mean (and standard error of the mean) adjusted for height in an analysis of covariance.^b In upper quartile of alcohol intake (>34 ml/day).^c P<0.05 in comparison with the day-day group; P-value <0.001 for ?.

Discussion

The purpose of this study was to determine the influence of shift work on biomarkers related to CVD. In studies on the effect of shift work on health, there have been some methodological problems regarding selection into shift work and selection out of shift work. Some studies have suggested that workers who drop out of shift work have a higher risk of CVD than workers who continue in shift work (19, 20). Thus, we analyzed data after grouping workers by their work schedule at baseline and at the end of an observation period of 10 years [the workers who continued shift work (shift-shift), those who

continued fixed daytime work (day-day), and those who changed work schedules during the observational period (day-shift and shift-day)]. The drawback of this study was the lack of a history on the work schedule between the baseline and the end point. In this company, however, selection into shift work or selection out of shift work had been decided mainly by the characteristics of each worksite instead of by individual circumstances, and changes were not frequently introduced into the work schedule. The entire length of the shift work was the longest among the shift-shift workers, followed by that of the shift-day workers, the day-shift workers, and the day-day workers. Therefore, the categorization used in

this analysis was considered to reflect the transition of work during the observational period and the history of shift work over the entire worklife. The definition of "shift work" in this analysis included both two-shift work and three-shift work to simplify the grouping by work schedule at baseline and the last year. In addition, the baseline data of the workers who dropped out of this follow-up study did not differ from those of the persons who were followed.

According to the results of this study, the variable most influenced by shift work was BMI. The largest increase in BMI was found among the workers who transferred from daytime work to shift work during the observational period (day–shift), followed by the increase among the workers who continued shift work (shift–shift). The significant increase in BMI among them remained after adjustment for other possible confounding factors, such as age, baseline BMI, and health-related behavior. Because several studies on this topic have used the cohort design, our data are important for showing a positive relationship between weight gain and shift work in a long-term cohort study. A short-term follow-up study reported that BMI decreased significantly among shift workers when they were compared with daytime workers after 1 year from the start of a new job (10). On the other hand, Niedhammer et al (15) found a positive relationship between shift work and excess weight or weight gain in a 10-year follow-up study. Gieliebtter et al (14) also came to a similar conclusion, although their data regarding weight gain were self-reported.

Recent reports have tended to show a higher prevalence of metabolic disturbances among shift workers (4–9), but some cohort studies have also been carried out. In our current study, we did not find any significant changes in biomarkers among shift workers when these workers were compared with daytime workers, although total cholesterol tended to increase more among the workers who continued shift work than among the workers who continued fixed daytime work. We reported that male blue-collar shift workers had a significantly higher risk of diabetes mellitus when compared with white-collar workers, but they did not have a significantly higher risk than blue-collar daytime workers (18). We have also reported an increased risk for the onset of hypertension among shift workers of younger ages in cohort studies (17). The effects of shift work on health may appear at different points for each parameter. Weight gain is one of the major risk factors for an increase in blood pressure and lipids and a decrease in glucose tolerance. Therefore, the greater increase in BMI among shift workers would have an influence on biological data after a period of time.

In our current study, the greater increase in BMI among the workers who continued shift work and the

workers who transferred from daytime work to shift work may have been caused by health-related behavior. However, the smoking and drinking habits of the groups did not differ at baseline or at the end point. Amelstort et al (10) reported that the number of cigarettes smoked per workday increased significantly among shift workers in a comparison with daytime workers, as shown in a 1-year follow-up study. However, overall, the influences of shift work on smoking and drinking habits have been found to be inconsistent (1).

We found a significant difference in the total calorie intake among the groups of workers in our study at the end point. The workers who continued to work shifts (shift–shift) consumed the highest number of calories, followed by the workers who transferred from daytime work to shift work (day–shift). Whether these differences were influenced by work schedule was unknown because we did not have data on the workers' diets at baseline. Studies into the influence of shift work on eating habits (21–23) have reported that shift work causes a circadian redistribution of food and that there is a tendency towards the consumption of cold and fast food, but the overall calorie intake did not differ between the shifts of each worker.

In summary, our results suggest that shift work is related to weight gain. This effect was more prominent among those who moved to shift work from daytime work. Some changes in dietary habits during the adaptation to shift work may be related to weight gain. In this cohort study, we did not find significant increases in blood pressure, serum lipid, or glycosylated hemoglobin. An increase in weight gain among shift workers would have had an influence on the biological data after a period of time.

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