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Objectives This study investigated the possibility of a relationship between blood pressure level and rotating 3-shift work in a prospective follow-up of workers in a zipper and aluminum sash factory in Japan.

Methods Altogether 1551 men aged 18—49 years were followed prospectively for 5 years, and the cumulative incidence of hypertension among 3-shift workers was compared with that of day workers. A multiple logistic analysis was used for adjusting for base-line characteristics such as age, body mass index, blood pressure, and drinking habit.

Results In the younger age group, the relative risk of the rotating 3-shift workers during the observational period was increased compared with that of day workers after adjustment for the confounding factors. In the older group, the cumulative incidence of hypertension was not higher for workers who had continued shift work. However, a relatively high risk of hypertension was found for workers who converted from 3-shift work to day work when compared with those who remained on shift work and day work.

Conclusions It is suggested that there is an association between 3-shift work and blood pressure.

Key terms blood pressure, follow-up study, incidence, industrial worker, shift worker.

Recent reports have shown an increased risk of ischemic heart disease among shift workers (1—9). However, the results of studies on the relationship between shift work and the traditional risk factors of ischemic heart disease have been controversial (10—18). Some studies found elevated serum triglyceride levels or lipoproteins (13—15) among shift workers, but few studies found an increase in blood pressure, serum cholesterol, and other risk factors. Selection bias is one of the greatest methodological problems when this issue is investigated (ie, the healthy worker effect) (19, 20). The aim of the present cohort study was to investigate the possibility of a relationship between blood pressure level and 3-shift work, with selection bias and confounding factors taken into account.

Subjects and methods

Subjects

The cohort consisted of all manual male workers ranging from 18 to 49 years of age in a Japanese zipper and sash factory. We followed the subjects from 1990 to 1995 and investigated the cumulative incidence of hypertension. All subjects with any of the following were excluded: high blood pressure in the base-line health examination [systolic blood pressure ≥140 mm Hg (≥18.62 kPa) and diastolic blood pressure ≥90 mm Hg (≥11.97 kPa), history of cardiovascular disease, diabetes, kidney disease, or any other chronic diseases]. The target population numbered 2000, and 1551 men were followed to the

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end (table 1). The subjects who had at least 5 annual health examinations during the 5-year period were included in the analysis. The follow-up rate was 77.6%.

Diagnosis

Hypertension was diagnosed on the basis of the following criteria: high blood pressure [systolic blood pressure ≥140 mm Hg (≥18.62 kPa) or diastolic blood pressure ≥90 mm Hg (≥11.97 kPa) or both] in the annual health examinations at least twice or the initiation of antihypertensive treatment. Blood pressure measurements were taken with a mercury sphygmomanometer from the right arm of the subjects while seated after 5 minutes of rest.

Occupations

The work schedules were 2 types, day work and rotating 3-shift work. The work schedules were taken from questionnaires administered in 1990 and 1995. Some workers who did shift work without night shifts were included in the group of day workers. In the factory, 3-shift workers were rotated counterclockwise. Two-thirds of them had a noncontinuous shift system (5 day shifts, 5 night shifts, and 5 evening shifts with 2 weekend rest days between successive shifts). One-third of them had a continuous shift system (4 day shifts, 4 night shifts, and 4 evening shifts or 3 day shifts, 3 nights shifts, and 3 evening shifts, with 1 rest day between successive shifts). Both systems changed shifts at 0800, 1630, and 0015 or 0630, 1300, and 2130. Some jobs, like operating machines which melted, heated, mixed, or casted are done by 3-shift workers. Construction aluminum products are the jobs of day workers. Other jobs are done by both workers.

The participants were classified into 1 of 4 groups according to work conditions in 1990 and 1995: (i) "day-day" workers, men who did day work in both 1990 and 1995, (ii) "day-shift" workers, men who did day work in 1990 and transferred to rotating 3-shift work during the observation period, (iii) "shift-day" workers, men who did 3-shift work in 1990 and transferred to day work during the observation period, and (iv) shift-shift workers, men who did 3-shift work in both 1990 and 1995.

The follow-up rate of the day workers was 74.9%, and that of the 3-shift workers was 82.8%, as shown in table 1. The cause of dropout was mainly resignation from the factory, the reasons for which were unknown. Table 2 shows the base-line characteristics of the subjects and the dropouts. The base-line characteristics according to the work conditions are shown in table 3.

Statistics

We analyzed data by 3 age groups (18—29, 30—39, and 40—49 years). The cumulative incidence of hypertension during the 5-year period was compared between the 4 groups according to their work conditions. By a multiple logistic analysis, the relative risks of hypertension among the 3-shift workers were evaluated after adjustment for other confounding factors. Age, body mass index (BMI), systolic blood pressure, and drinking habit at the time of the base-line examination were allowed in the model. Age, BMI, and blood pressure were used as

Table 1. Follow-up rate by age and type of work schedule in 1990.

	Number at base line	Subjects followed	
		N	%
Age (years)			
18—29	567	452	79.7
30—39	731	568	77.7
40—49	702	531	75.6
Type of work schedule			
Day work	1331	997	74.9
Shift work	669	554	82.8
Total	2000	1551	77.6

Table 2. Comparison of the base-line characteriscs of the subjects who were followed and those who dropped out.

Type of work schedule in 1990	N	Age (years)		Length of employment (years)		Body mass index[a]		Systolic blood pressure (mm Hg[b])		Diastolic blood pressure (mm Hg[b])		Habitual drinking[c] (%)	Current smoking (%)	Lack of leisure-time sport[d] (%)
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Day work														
Followed subjects	997	35.4	8.0	15.5	9.3	22.1	2.5	117	10.9	69	9.1	20.6	66.1	64.9
Dropouts	334	36.0	8.5	15.8	7.9	22.4	2.6	116	10.4	69	8.7	24.1	68.5	64.2
Shift work														
Followed subjects	554	33.4	8.4	13.5	7.9	22.3	2.7	119	10.4	70	8.9	23.7	66.4	70.6
Dropouts	115	34.8	8.9	13.5	7.5	22.1	2.7	118	9.3	71	9.3	26.9	59.6	64.0

[a] Body mass index = height (cm)/weight (kg)^2.
[b] 1 mm Hg ≈ 0.133 kPa.
[c] Habitual drinker: drinking more than 5 times per week.
[d] Lack of leisure-time sport: participation less than once per week.

Table 3. Base-line characteristics according to work conditions in 1990 and 1995.

Type of work schedule in 1990—1995	N	Age (years)		Length of employment (years)		Body mass index[a]		Systolic blood pressure (mm Hg[b])		Diastolic blood pressure (mm Hg[b])		Habitual drinking[c] (%)	Current smoking (%)	Lack of leisure-time sport[d] (%)
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Day-day	924	35.5	8.0	16.0	7.9	22.1	2.5	117	11	69	9.2	21.1	66.0	64.3
Day-shift	73	33.7	8.0	13.3	6.9	22.2	2.7	119	10.5	70	8.6	15.1	63.0	57.5
Shift-day	180	33.2	8.0	13.6	7.1	22.4	2.5	119	9.5	70	8.5	21.7	65.6	67.8
Shift-shift	374	33.5	8.5	13.4	7.6	22.2	2.7	118	10.8	70	9.1	22.7	66.3	70.1

[a] Body mass index = height (cm)/weight (kg)^2. [b] 1 mm Hg = 0.133 kPa. [c] Habitual drinker: drinking more than 5 times per week.
[d] Lack of leisure-time sport: participation less than once per week.

Table 4. Cumulative incidence of hypertension by type of work schedule (1990—1995). (95% CI = 95% confidence interval)

Age in 1990	Subjects (N)	Cumulative incidence of hypertension		
		N	%	95% CI
18—29 years				
Day-day	228	8	3.5	1.1—5.9
Day-shift	25	1	4.0	0—11.7
Sift-day	65	2	3.1	1.1—7.3
Shift-shift	134	16	11.9	6.4—17.4
All	452	27	6.0	3.8—8.2
30—39 years				
Day-day	339	21	6.2	3.6—8.8
Day-shift	28	0	0.0	0—0
Sift-day	70	4	5.7	0.3—11.1
Shift-shift	131	4	3.1	0.1—6.1
All	568	29	5.1	3.3—6.9
40—49 years				
Day-day	357	30	8.4	5.5—11.3
Day-shift	20	3	15.0	0—30.6
Sift-day	45	8	17.8	6.6—29.0
Shift-shift	109	12	11.0	5.1—16.9
All	531	53	10.0	7.4—12.6
All ages combined				
Day-day	924	59	6.4	4.8—8.0
Day-shift	73	4	5.5	0.3—10.7
Sift-day	180	14	7.8	3.9—11.7
Shift-shift	374	32	8.6	5.8—11.4
All	1551	109	7.0	5.7—8.3

continuous variables, and drinking habit was used as a categorized variable (drinking less than 5 times per week or drinking 5 or more times per week).

Results

Among the 1551 subjects, we found 109 displaying an onset of hypertension. The cumulative incidence of hypertension for all of the subjects was 7.0% (table 4). With all the age groups combined, we did not find any difference in the cumulative incidence between the 4 groups according to the work conditions. However, when we compared the cumulative incidence between the 4 groups in each 10-year age category, different results were shown between the groups. Among the workers aged 18—29 years, the cumulative incidence of hypertension among the "shift-shift" workers, who did shift work in both 1990 and 1995, was the highest (11.9%) and the cumulative incidence of the other 3 groups was almost the same, showing 3.0—4.0%. For the 30- to 39-year-olds, we did not find any difference among the 4 groups. For the workers aged 40—49 years, the cumulative incidence of the "shift-day" workers, who transferred from shift work to day work during the observation period, was the highest (17.8%), followed by "day-shift" workers, "shift-shift" workers, and "day-day" workers.

Table 5. Relative risks (RR) for hypertension among the shift workers on different work schedules (1990—1995) according to multiple logistic analyses for each age category. (BMI = body mass index, SBP = systolic blood pressure, drinking = drinking more than 5 times per week or not, 95% CI = 95% confidence interval)

Age	Adjustment for age		Adjustment for age, BMI, SBP, drinking	
	RR	95% CI	RR	95% CI
18—29 years				
Day-day	1	.	1	.
Day-shift	1.3	0.015—10.4	1.3	0.15—11.3
Sift-day	1.0	0.20—4.59	1.1	0.22—5.4
Shift-shift	4.0	1.67—9.67	3.6	1.41—9.1
30—39 years				
Day-day	1	.	1	.
Sift-day	1.1	0.37—3.28	0.9	0.28—2.9
Shift-shift	0.6	0.19—1.69	0.4	0.14—1.4
40—49 years				
Day-day	1	.	1	.
Day-shift	2.0	0.56—7.47	2.6	0.57—12.2
Sift-day	2.5	1.08—5.91	2.4	0.93—6.0
Shift-shift	1.4	0.69—2.80	1.2	0.55—2.7

We analyzed the relative risks of hypertension for the 3-shift workers in a multiple logistic analysis (table 5). When the group of "shift-shift" workers was compared with the group of "day-day" workers in the 18—29 year age group, the relative risk was significantly high, 4.0 after adjustment for age and 3.6 after adjustment for age and other confounding factors, such as BMI, systolic

blood pressure, and drinking habit. The risks of the group of "day-shift" workers and "shift-day" workers were almost the same as that of the "day-day" workers. In the 30- to 39-year age group we did not find any higher risk of hypertension for the shift workers. Among the subjects aged 40—49 years, we could not find any higher risk among the "shift-shift" workers. When the group of the "shift-day" workers was compared with the "day-day" workers, the relative risk was significantly high, 2.5 after adjustment for age only. Although the relative risk of that group was diminished when the other confounding factors were allowed in the model, it was suggested that the workers who quit shift work had a higher risk of hypertension compared with the other groups.

Discussion

The purpose of the present study was to determine the influence of shift work on blood pressure. It has been recognized that shift work may be a risk factor for ischemic heart disease in some recent cohort studies (1—9). If irregular workhours increase coronary risk, its mechanism is not clear, and there is no study that indicates the effect of shift work on blood pressure. In the studies of the effect of shift work on health, there were some major methodological problems regarding selection into shift work and selection out of shift work (19, 20). Some studies suggested that the workers who dropped out of shift work had a higher risk of ischemic heart disease than the workers who continued shift work (1, 3). The longer the workers stay on their jobs, the greater the possibility may be of their being rotated when their physical condition is taken into account. Hence we analyzed data with stratification by age and distinguished the workers who had continued 3-shift work from those who had stopped shift work.

In the younger age group, under 30 years of age, the cumulative incidence of hypertension among the workers who did 3-shift work from the base line to the end point was about 3 times higher than that of the workers who continued day work. The relative risk of the former compared with that of the latter was significantly high after adjustment for confounding factors such as BMI, age, habitual drinking, and base-line blood pressure. Because the younger age group had less opportunity to be rotated according to their physical condition, it is suggested that 3-shift work has an influence on blood pressure. Among the workers 30—39 and 40—49 years of age, we could not find a high risk of hypertension for the workers who had continued shift work. However, we found a relatively high risk of hypertension for the workers aged 40—49 years who converted from shift work to day work (when compared with the others). Although we could not investigate the reasons for their removal from shift work, the workers who continued shift work until an older age may have been healthier than the others.

Although our findings suggest that shift work affects the onset of hypertension, we have to consider some factors which might influence the results of this study, such as the misclassification of work conditions and the misdiagnosis of hypertension, the previous occupational history of the workers, and the difference between the jobs and tasks of the 3-shift and day workers. We thought that the misclassification of the work conditions was few, since the work schedules were asked directly from the subjects in a questionnaire administered at the time of the base-line and end-point examinations. We also thought that there were few misdiagnoses since hypertension was diagnosed according to the criteria mentioned in the Methods section. Moreover, only workers who had ≥4 annual health examinations were included in the study.

We could not allow the length of exposure of irregular shifts into the analyses because the previous occupational histories of the workers were not known. However, since most of the employees of this factory were employed immediately after graduation, they did not have other occupational histories. In addition, because there were few workers who changed from fixed day work to 3-shift work, we assumed that the length of exposure to irregular shifts among the 3-shift workers in 1990 was almost equal to their time in employment. We did not take into account the difference in jobs and tasks, for example, physical activity between 3-shift workers and day workers. There are some differences in the jobs of 3-shift workers and day workers. However, because many of the manufacturing processes were automated, it seemed that the physical activity did not significantly differ between the day workers and 3-shift workers. Hence, although there were a few insufficiencies in the information on occupational history and work load, we conclude that an association between 3-shift work and hypertension is suggested by our study.

Some studies on the ambulatory measurement of blood pressure among shift workers indicate that the elevation of blood pressure among shift and night workers is caused by differences in the diurnal-nocturnal blood pressure rhythm and that it does not always cause definite hypertension (21—25). Our results suggested a chronic effect on the blood pressure of shift workers. In order to determine whether high blood pressure at younger ages causes hypertension at their age or not, a longer observation period is required.

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