Original article

Scand J Work Environ Health 2007;33(6):425-434

doi:10.5271/sjweh.1170

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Refers to the following texts of the Journal: 2005;31(4):291-299 1999;25(3):272-277 1997;23(4):257-265 2001;27(2):97-105 1999;25(4):376-381

The following articles refer to this text: 2007;33(6):401-404; 2009;35(3):163-179; 2009;35(6):466-474; 2010;36(2):180-182; 2010;36(6):515-516; 2013;39(6):559-567; 2018;44(3):229-238; [online first; 18 November 2019]

Key terms: blood pressure; coronary heart disease; job-exposure matrix; longitudinal study; occupational noise; physical workload; register linkage; shift work

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/18327510

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Shift work, occupational noise and physical workload with ensuing development of blood pressure and their joint effect on the risk of coronary heart disease

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Virkkunen H, Härmä M, Kauppinen T, Tenkanen L. Shift work, occupational noise and physical workload with ensuing development of blood pressure and their joint effect on the risk of coronary heart disease. *Scand J Work Environ Health*. 2007;33(6):425–434.

Objectives The change in systolic blood pressure (SBP) over an 8-year period was explored in groups defined according to exposure to shift work, occupational noise, and physical workload. The impact of baseline SBP and its increase in the relation to coronary heart disease (CHD) risk due to these exposures was also studied.

Methods The study cohorts (N=1288 for CHD follow-up, N=884 for SBP follow-up) consisted of industrially employed middle-aged men from the Helsinki Heart Study. Shiftwork status was obtained from a questionnaire, and other exposures were determined with the Finnish job-exposure matrix. SBP was measured in the Helsinki Heart Study, and CHD end points were obtained from official Finnish registers. The joint effects of baseline SBP, its change, and the exposure in question were estimated via Cox's regression models.

Results During the SBP follow-up, the steepest SBP gradient was found for physical workload only and physical workload combined with noise; shift work alone or combined with noise primarily entailed a lower mean SBP level than no such exposure. However, the shift workers had a relative risk of 1.71 [95% confidence interval (95% CI) 1.01–2.87] even without an increase in SBP, but, with a baseline SBP of ≥140 mmHg and an additional increase, their relative risk rose to 4.62 (95% CI 2.31–9.24) when they were compared with day workers with an SBP of <140 mmHg and no increase.

Conclusions In general, shift workers do not develop higher SBP levels than day workers, but, if they do, it entails high CHD risk. Noise shows a similar pattern. In contrast, physical workload entails a significant increase in SBP, and SBP is a key pathway to CHD risk.

Key terms job exposure matrix; longitudinal study; register linkage.

Noise, shift work, and physical workload are very common exposures during work and are frequently concurrent. The effects of these exposures (usually one at a time, disregarding other exposures) on the development of blood pressure, hypertension, or the risk of coronary heart disease (CHD) have been studied for decades with both positive and negative findings.

Most studies on noise exposure and blood pressure or hypertension have shown a positive association (1–7), but there are also studies that have not found any association between noise exposure and blood pressure or hypertension and other cardiovascular diseases (8–10). In his review of 1989, Kristensen (8) ascertained that, in over 50% of studies, weak correlations, no correlations, and even negative correlations have been found between noise exposure and the risk of hypertension and other cardiovascular diseases. According to a later meta-analysis by van Kempen et al (11), the relationship between noise exposure and CHD is still inconclusive. However, in our previous study of the long-term effect of occupational noise, the estimates of CHD risk in association with exposure to continuous and impulse noise varied between 1.22 and 1.54 depending on the reference group used and the covariates adjusted for (12).

Shift work is also usually associated with hypertension, but both positive (13–15) and negative (16–20) relationships have been reported. There is increasing evidence showing that shift work is a risk factor for CHD (21–24), although contrasting findings do indeed exist (25).

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As far as we know, there are no studies on the association between physical workload and blood pressure or hypertension, while at least two studies have found a positive association between physical workload and CHD (23, 26).

All of these exposures are thus potential risk factors for CHD and call for preventive measures. The fact that these factors tend to occur in combination complicates prevention (23, 27). It would be important to ascertain which of these exposures is(are) the true culprit(s) with respect to CHD risk and what the pathways for that risk are. In our previous study, we dealt in detail with the joint effects of these three factors on CHD risk (23). In our present study, the focus was on blood pressure and hypertension with the following two aims: (i) we studied the change in systolic blood pressure (SBP) over an 8-year period in groups defined on the basis of their exposure to shift work, occupational noise, and physical workload and (ii) we explored the impact of baseline SBP and an increase in it on CHD risk due to these exposures.

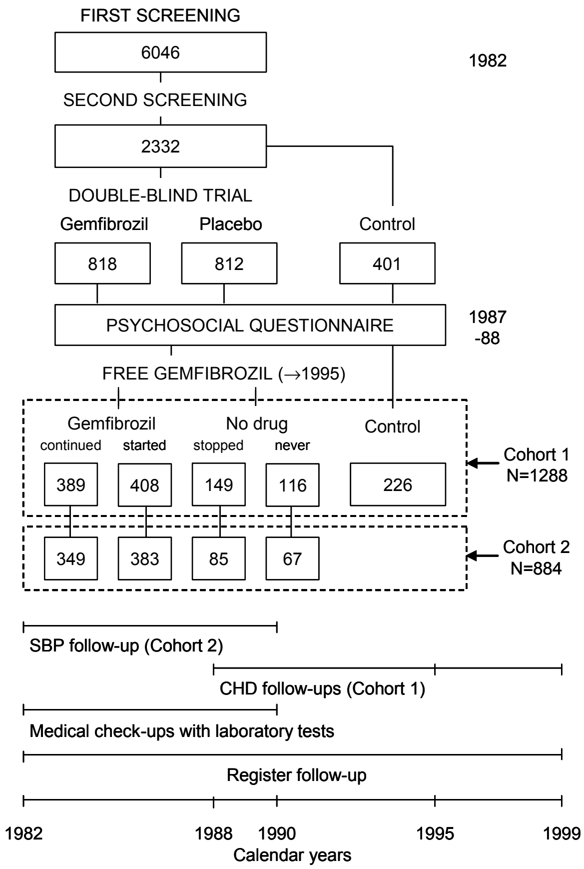

Figure 1. Numbers of industrially employed participants in different phases of the Helsinki Heart Study (CHD = coronary heart disease, SBP = systolic blood pressure).

Study population and methods

Study population and follow-up via linkage to population registers

The Helsinki Heart Study was a 5-year randomized, double blind, placebo-controlled primary prevention trial concerning gemfibrozil, a lipid-lowering drug, with middle-aged men (40–55 years of age at entry) (28). The participants were selected for the trial via two successive screenings (in 1980–1982) at two government agencies (N=12 893) and five companies (N=6046) involved in mechanical engineering, paper and pulp, or oil industries. The exclusion criteria at both screenings were a nonhigh-density lipoprotein cholesterol level of <5.2 mmol/l, CHD, any other major illness, or any combination of the three. A control group was formed of the participants with a nonhigh-density lipoprotein cholesterol level of ≥5.2 mmol/l in the first screening, but a level of <5.2 mmol/l in the second screening. A secondary prevention trial consisted of those who fulfilled the lipid criterion at both screenings but had symptoms of CHD. After the double blind trial, all of the trial participants were offered free gemfibrozil until the end of 1995, and they could continue in an "open-label" trial with two annual examinations whether or not they chose treatment with gemfibrozil. In addition, at the end of the double blind trial, a psychosocial questionnaire was sent to all of those who participated in the primary and secondary trials, and also to those in the control group.

Study population for the present study

The requirement of a long-term follow-up of blood pressure among industrial workers meant that the information needed was available for only part of the study population of the Helsinki Heart Study (figure 1). First, they should have participated in the trials or in the control group, and they should have responded to the psychosocial questionnaire (for information about shift work). The 71% response rate resulted in 1450 men. With the additional exclusion of those who, despite responding to the questionnaire, did not give information about shift work (N=109) or were night workers (N=2) or part-time workers (N=14) or had no occupational code (N=5) or did not have blood pressure measurements at least from the first and the fifth years (N=32), the cohort consisted of 1288 men. Cohort 1 was thus formed at the time the psychosocial questionnaire was administered and after the double blind trial. A subpopulation of cohort 1, cohort 2 (N=884), had all blood pressure measurements starting from the beginning of the study and continuing until 1990, a total of 8 years. As the control group (N=226) did not have an 8-year follow-up, they were excluded. As CHD events, as well as any major illness, were considered a reason to discontinue the trial, the workers with such experiences were also excluded from cohort 2, which thus consisted of relatively healthy and compliant participants.

The selection procedure obviously caused cohorts 1 and 2 to be more dyslipidemic than a normal population. However, the mean SBP at the first screening was 140.4 mmHg in the source population (N=6046), 141.4 mmHg in cohort 1, and 141.4 mmHg in cohort 2.

For the follow-up of CHD the cardiac end points were obtained from the Hospital Discharge Register (kept by the National Research and Development Centre for Welfare and Health) and the Register of Deaths (kept by Statistics Finland). Several studies have found these registers to be accurate enough for epidemiologic studies on CHD (29–30). Because of the long follow-up, the definition of CHD was based on codes 410–414 of the International Classification of Diseases (ICD), 8th and 9th versions, for the years 1982–1995 and I20–I25 of the ICD, 10th version, for the years 1996–1999. Cohort 1 was followed for CHD from 1988 to the end of 1999 with a mean follow-up time of 10.6 years. By the end of 1999, there had been 288 coronary events, of which 35 were fatal.

Among the participants, there were 244 men who were already retired when they completed the questionnaire. However, we decided to include all of the participants in the study for purposes of examining the long-term effects. The average age of retirement in Finland is 59 years (31), and at the end of 1999, 91.3% of the men were aged 59 years or older, if alive.

Shiftwork status and occupation

Shift work was recorded in the psychosocial questionnaire (day work, part-time work, 2-shift work, 3-shift work, irregular work, and night work). Irregular work was a minority in this sample. In the analyses, a dichotomized variable was used (day and shift work, all other types of work combined). Most of the participants in the shift work groups (93.3%) had reported that they had worked their shift work schedules for more than 5 years.

Occupational information was based on the 3-digit occupational code used in the 1980 census—a Finnish version of the Nordic Classification of Occupations of 1965 (32), obtained by record linkage with Statistics Finland. The linkage was based on personal identification numbers. We considered major occupational classes 0, 1, and 2 to be white-collar work and classes 3 to 9 to be blue-collar work. The four biggest blue-collar occupational classes were paper and board mill workers, forestry supervisors, forklift operators and the like, and sawyers (a total of 29.7% of blue-collar workers). Altogether 46.4% of the white-collar workers were technicians in chemical or mechanical engineering or technicians working in other branches of engineering.

Linkage to the Finnish job-exposure matrix for estimates of exposure to noise or perceived physical workload

The Finnish job-exposure matrix (FINJEM) is a multipurpose information system covering major occupational exposures occurring in Finland since 1945 (33). The proportion of those exposed and the mean level of exposure from the period 1985–1994 were linked to our data using a 3-digit occupational code.

Occupational exposure to impulse noise was considered to be exposure to noise entailing impulses for which the equivalent dose in decibels underestimates the risk of noise-induced hearing loss (34). The proportion of those exposed to continuous or impulse noise was either 100% or 0% (ie, either exposed or not) so that, in the analyses, only the mean level of exposure was used. The mean level of noise exposure among 624 (48.4%) of the men exposed ranged from 80 to 100 dBA. Of these, 134 (10.4% of all) were also exposed to impulse noise. In the analyses, workers were considered to be exposed to noise if they were exposed to continuous (≥80dB) or impulse noise or both. If a man was exposed to impulse noise, he was also exposed to continuous noise.

In the FINJEM, perceived physical workload refers to tasks in which the work requires dynamic work of the large muscle groups. The exposure estimates were based on data of the survey of work conditions carried out by Statistics Finland in 1990. About 4000 salaried workers were interviewed in this survey. Those reporting that their work was physically rather heavy or very heavy were considered to be exposed (33). The exposure metric used in our study was the product of the proportion of the exposed and the mean level of exposure in that occupation. In the analyses this variable was categorized into tertiles (no, low, or medium–high exposure).

Blood pressure, smoking and treatment with gemfibrozil

The participants in the trial groups had their blood pressure measured four times per year, and the control group underwent blood pressure measurement once a year. The blood pressure of the participants was measured by experienced nurses at the workplace clinics using calibrated mercury sphygmomanometers with cuffs measuring 10 to 12 cm × 40 cm. The measurement was carried out with the participants in a sitting position before their blood was sampled. In this study hypertension was defined as a systolic blood pressure (SBP) of ≥140 mmHg or a diastolic blood pressure (DBP) of ≥90 mmHg.

Smoking habits were also recorded in a questionnaire at the first screening visit (daily consumption of cigarettes), and a dichotomous variable [current smokers, nonsmokers (including ex-smokers)] was used in the analyses.

Most of the participants in our present study had participated in the clinical trial, and, during our follow-up, 73.4% of the study population was on gemfibrozil. The treatment group was thus used as a covariate when CHD risk was estimated.

Statistical analysis

To study the effect of shift work, noise, and physical workload on the change in SBP over the 8-year period, we grouped the study population in two different ways according to exposure. First, we formulated all of the possible combinations of these three exposures, calculated the annual mean values of SBP for all of those who had their SBP measured every year of the follow-up (N=884 in cohort 2), and presented graphs of the change in SBP according to exposure combinations. A one-way analysis of variance (ANOVA) was used to compare the differences between the exposure groups, and paired samples t-tests were used to compare the means of the first and last years. Second, the same cohort was used to explore the change in SBP according to different levels of one specific exposure, and the study population was divided into groups by the level of the exposure in question, ignoring the other exposures.

We further studied the effect of an increase of >10.0 mmHg in SBP on CHD risk for those with a baseline level of <140 or ≥140 mm Hg, together with exposure or nonexposure, the exposure being shift work, noise, or physical workload. We thus formed a dummy variable system on the basis of a (2 × 2 × 2) risk variable (SBP change × SBP baseline × exposure) and used Cox's models to estimate the relative risks with and without covariates. To study the short-term and long-term effects of the exposures on CHD risk, we followed cohort 1 (N=1288) from 1988 to 1995 (8 years) and to 1999 (12 years). The analyses were performed with the statistical package SPSS 14.0 for Windows (SPSS Inc, Chicago, IL, USA).

Results

Triad of shift work, noise and physical workload

The three exposures overlapped to a high degree. Of the 475 shift workers (table 1), only 8.8% were exposed to shift work only, but, of this group, 54.5% was also exposed to both noise and physical workload. Similarly, the exposure of "noise only" was rare, but noise often occurred in combination with physical workload or with both physical workload and shift work. Physical workload was a common exposure in that, of all of those exposed (N=884), 82.1% were exposed to physical workload, generally in combination with noise or shift work.

Most of the white-collar workers were unexposed or exposed to shift work only (table 1). None of the white-collar workers were exposed to noise. In contrast, among those working in manufacturing and related works (occupational classes 6 and 7), <1% were unexposed. Physical workload, alone or in combination, was the most common exposure in these occupational classes.

The greatest difference for smoking was found between those in the "no exposure" and those in the "shift work only" groups (30.7% versus 42.9%). There were only slight differences in the first year's mean levels for total serum cholesterol. The mean SBP and DBP levels were highest, 138.4 mmol/l and 90.0 mmol/l, respectively, for those exposed to noise only. The mean SBP level was lowest, 133.9 mmol/l, for the shift workers exposed also to noise, and the shift workers without

Table 1. Percentage distribution of the exposure groups by occupational classes, prevalence of smoking, and first year's means and standard deviations (SD) for systolic and diastolic blood pressure and total serum cholesterol among industrially employed workers.

Exposure group	N	Occupational classes [a] (%)						Smoking (%)	Systolic blood pressure (mmHg)		Diastolic blood pressure (mmHg)		Total cholesterol (mmol/l)	
		0–2	3	5	6	7	Other		Mean	SD	Mean	SD	Mean	SD
No exposure	404	89.3	87.0	22.4	0.3	0.2	0	30.7	134.1	13.9	87.2	8.7	6.7	0.7
Shift work only	42	8.8	0	10.2	0.3	1.0	0	42.9	134.1	15.4	86.3	10.1	7.2	1.1
Noise only	35	0	0	32.7	0.6	4.2	0	28.6	138.4	13.2	90.0	9.2	6.8	0.8
Physical workload [b] only	125	1.4	0	12.2	19.6	9.2	18.2	36.0	137.5	13.2	89.5	8.6	6.8	0.7
Shift work + noise	81	0	0	12.2	0	18.6	0	40.0	133.9	13.5	86.5	7.9	6.5	0.7
Shift work + physical workload [b]	93	0.6	0	8.2	3.9	13.6	54.5	36.6	135.5	13.1	88.5	8.0	6.7	0.8
Noise + physical work load [b]	249	0	10.4	0	47.7	15.1	21.2	34.9	135.0	13.9	87.4	8.7	6.7	0.8
Shift work + noise + physical workload [b]	259	0	2.6	2.0	27.8	38.0	6.1	36.7	136.3	12.4	88.3	8.8	6.8	0.8
Total	1288	363	77	49	363	403	33	34.6	.	.	.	.	.	.

[a] 0–2 white-collar (0 = technical, physical, science, social science, humanistic and artistic work; 1 = administrative, managerial and clerical work; 2 = sales work); 3 agriculture, forestry, commercial fishing; 5 transport and communications work; 6 fine mechanical work, iron and metal ware work, electrical work, wood work; 7 graphic work; glass, ceramic and clay work; chemical processing and related work.

[b] Exposure to physical workload present when the product of the prevalence and level was in the second or third tertile.

exposure to noise or physical workload had the lowest mean DBP level, 86.3 mmol/l.

Change in systolic blood pressure on the basis of all combinations of the three exposures

Figure 2 shows the findings from cohort 2, in which all of the participants had a complete series of measurements.

During the first 2 or 3 years, the mean SBP level decreased in all of the exposure groups. This change can be considered to be a trial effect, as the participants received (in both phases of the trial) intense health counseling, in addition to the lipid-lowering drug. However, gradually, the effects of the health education wore off, and the participants' SBP level started to increase. At the end of the open-label phase, the mean SBP level was higher than at its beginning in all of the groups except the "noise only" group. In figure 2, the SBP of the "physical workload only" and the combinations containing physical workload are constantly above those of the "no exposure" group throughout the 8-year follow-up, while those of the "shift work only" or "shift work and noise" group are close to those of the "no exposure" group. Table 2 presents the tests related to the findings shown graphically in figure 2, and it confirms the role of physical workload with respect to SBP. When the means of the first and last years of the follow-up are compared, a significant or close-to-significant increase in SBP was found for exposure to "physical workload only", "noise and physical workload", and the "all three" groups. As cohort 2 was necessarily a "healthy cohort of survivors", we compared the findings with those from the original background cohort (N=1320), for which all available persons were included whether or not they had a complete follow-up. The findings were essentially similar to those shown in figure 2 (results not shown).

Change in systolic blood pressure according to the main exposure groups

Figure 3 shows the mean SBP levels for the different categories of noise, shift work, and physical workload when no attention has been paid to concurrent exposures. The mean SBP of those not exposed to noise was lower than that of those exposed to continuous noise, but the SBP of those exposed to both continuous and impulse noise was fairly inconsistent in this respect. The SBP mean levels of the 3-shift workers and day workers were similar throughout the follow-up, but those with 2-shift or irregular shift work had constantly higher levels. The fact that 67.7% of the 2-shift workers but only 21.8% of the

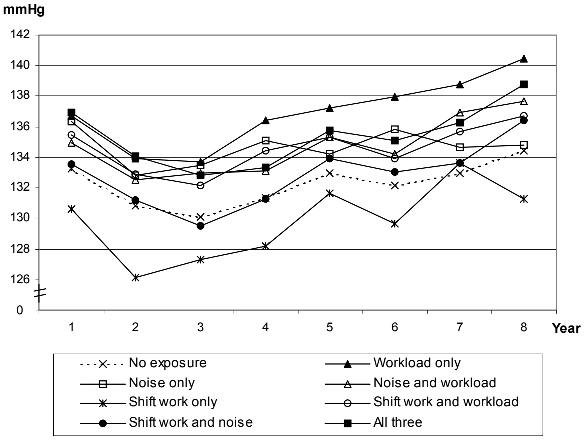

Figure 2. Mean levels of systolic blood pressure according to different combinations of occupational exposures among the industrially employed workers.

Table 2. Level of systolic blood pressure and hypertension during the first and last year of the 8-year follow-up among the industrially employed workers (cohort 2) in groups formed on the basis of exposure to shift work, noise, and physical workload.

Exposure group	N	Mean age [a] (years)	First year of follow-up				Last year of follow-up				t-Test to compare means of first and last year (P-value)
			Systolic blood pressure (mmHg)			Hypertensives [b] (%)	Systolic blood pressure (mmHg)			Hypertensives [b] (%)	
			Mean	SD	P-value [c]		Mean	SD	P-value [c]		
No exposure	285	52.5	133.3	12.7	·	43.9	134.5	14.7	·	51.9	0.09
Shift work only	27	52.6	130.6	15.0	0.97	33.3	131.3	13.4	0.96	51.9	0.77
Noise only	22	55.0	136.4	10.2	0.95	63.6	134.8	13.6	1.00	68.2	0.57
Physical workload [d] only	81	52.1	136.7	13.8	0.38	51.9	140.5	14.9	0.02	61.7	<0.01
Shift work + noise	55	51.6	133.5	12.2	1.00	41.8	136.4	16.6	0.98	49.1	0.15
Shift work + physical workload [d]	62	52.2	135.4	13.4	0.92	59.7	136.7	15.1	0.96	66.1	0.48
Noise + physical workload [d]	169	53.1	134.9	12.8	0.87	49.1	137.7	14.9	0.31	57.4	<0.01
Shift work + noise + physical workload [d]	183	51.8	136.9	11.8	0.05	53.6	138.8	14.6	0.04	60.7	0.05

[a] Age at baseline.
[b] According to the criterion of ≥140 mmHg for systolic blood pressure or ≥90 mmHg for diastolic blood pressure.
[c] Two-way (age included) analysis of variance, posthoc (Tukey HSD) comparison for the difference from the no exposure group.
[d] Physical workload exposure present when the product of the prevalence and level was in the second or third tertile.

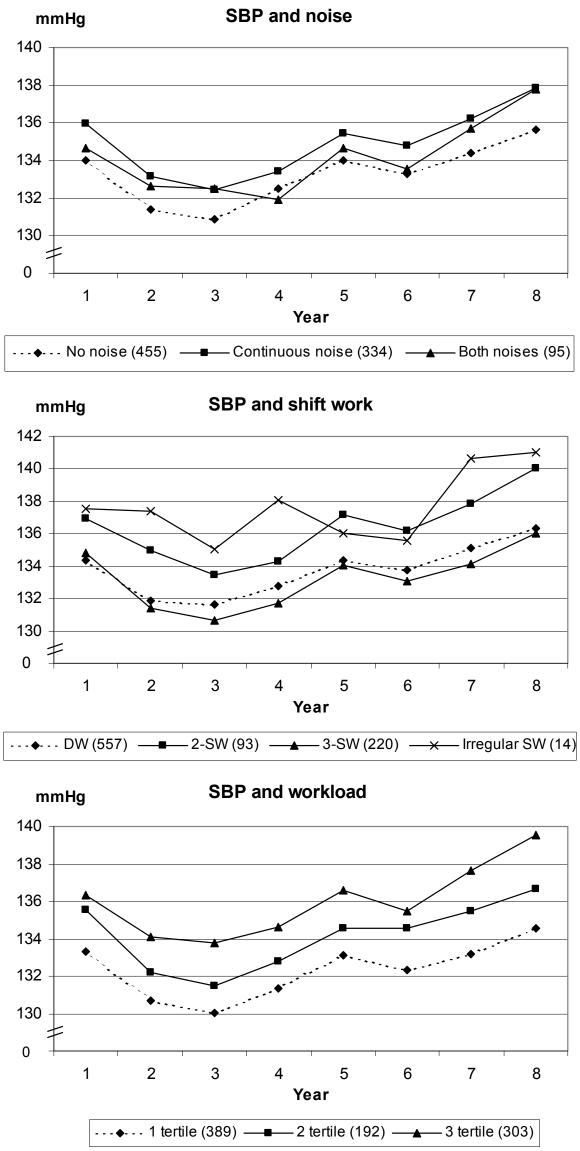

Figure 3. Mean levels of systolic blood pressure (SBP) according to occupational exposures among the industrially employed workers. Number of workers in parentheses. (DW = day work, SW = shift work)

3-shift workers belonged to the third tertile of exposure to physical workload may offer some explanation for the differences between the shiftworker groups, as the clearest differences between the mean SBP levels were found for the tertiles of physical workload. During the 8-year follow-up, the unexposed workers had the lowest SBP levels, and those in the third exposure tertile for physical workload had the highest levels.

Role of an increase in systolic blood pressure in the risk of coronary heart disease due to exposure to shift work, noise or physical workload

We finally explored the joint effects of the baseline SBP level, its increase, and the occupational exposure in question (table 3). The study population was divided into groups according to the occupational exposure in question, their mean SBP level during the first year of the Helsinki Heart Study (<140 versus ≥140 mmHg), and the change in SBP level between the first and the last year. If the SBP level decreased, did not change, or increased ≤10.0 mmHg, SBP was considered to be "not elevated".

The combination of shift work and elevated SBP showed the greatest risk of CHD. Compared with day workers who were normotensive (in terms of SBP <140 mmHg) in the first year and whose mean level did not change (reference group), all other combinations had a significant risk of CHD in both follow-ups. There were even factors other than hypertension in the pathway between shift work and CHD risk as the relative risk of normotensive shift workers, when compared with normotensive day workers, was 1.71 ($P=0.04$). Shift workers whose SBP was ≥140 mmHg in the first year and showed an increase of >10.0 mmHg during follow-up had a short-term relative risk of 4.62 ($P<0.001$) and a long-term relative risk of 3.59 ($P<0.001$).

The combination of elevated SBP and noise exposure was also a risk factor for CHD. When followed to the end of 1995, those whose SBP was elevated at the beginning of the study and for whom it still increased had a relative risk of 3.44 ($P<0.001$). The long-term relative risk was 3.06 ($P<0.001$).

The normotensive workers who were exposed to physical workload had a relative risk of 0.96 ($P=0.88$) when they were compared with the normotensive workers who were not exposed to physical workload. In addition, if the workers exposed to physical workload had an SBP of <140mmHg and had an increase of >10.0 mmHg, their relative risk was 2.03 ($P<0.01$) in the short-term follow-up and 2.27 ($P<0.001$) in the long-term follow-up, both relative risks being very close to those of the corresponding groups among those not exposed to physical workload. However, with both an elevated baseline SBP level and a subsequent increase in it, the relative risk was 3.33 ($P<0.001$) in the shorter follow-up and 3.27 ($P<0.001$) in the longer follow-up. These risks were approximately twice that seen in the corresponding groups among those not exposed to physical workload. The excess CHD risk associated with physical workload seems thus to go predominantly through markedly elevated levels of SBP. With each of the occupational exposures, adjustment for age and smoking (factors that can be considered to be both effect mediators and confounders) brought some changes in the risk patterns. Adjustment for the other exposures (potential confounders) slightly decreased the relative risks, but they remained significant for the most part. Similarly, adjustment for treatment with gemfibrozil did not essentially change the estimates.

Table 3. Systolic blood pressure (SBP) during the first year of the Helsinki Heart Study, the SBP change, and shift work, noise or physical workload as a predictor of coronary heart disease (CHD) risk among industrially employed men (cohort 1) for different follow-ups. The relative risks (RR) with 95% confidence intervals (95% CI) and P-values were derived using Cox proportional hazards models with different covariates.

Time of follow-up	Elevated SBP [a]	N	CHD cases (N)	Unadjusted		Adjusted for age and smoking		Adjusted [b]	
				RR	95% CI	RR	95% CI	RR	95% CI
Follow-up until 1995									
Day work									
<140 SBP (1st year)	No	377	29	1		1		1	
<140 SBP (1st year)	Yes	136	26	2.62	1.54–4.45 [c]	2.44	1.43–4.15 [d]	2.56	1.5–4.36 [c]
≥140 SBP (1st year)	No	253	43	2.36	1.48–3.78 [c]	2.33	1.45–3.73 [c]	2.33	1.45–3.74 [c]
≥140 SBP (1st year)	Yes	47	9	2.73	1.29–5.78 [d]	2.44	1.15–5.16 [e]	2.71	1.28–5.74 [d]
Shift work									
<140 SBP (1st year)	No	220	28	1.71	1.01–2.87 [e]	1.71	1.01–2.87 [e]	1.59	0.93–2.71
<140 SBP (1st year)	Yes	87	16	2.57	1.40–4.73 [d]	2.57	1.39–4.73 [d]	2.43	1.31–4.52 [d]
≥140 SBP (1st year)	No	133	24	2.52	1.47–4.33 [c]	2.38	1.39–4.10 [d]	2.37	1.36–4.12 [d]
≥140 SBP (1st year)	Yes	35	11	4.62	2.31–9.24 [c]	4.25	2.11–8.53 [c]	4.29	2.12–8.72 [c]
Noise exposure [f]									
No									
<140 SBP (1st year)	No	321	27	1		1		1	
<140 SBP (1st year)	Yes	105	14	1.64	0.86–3.12	1.91	1.24–2.92 [d]	1.60	0.84–3.05
≥140 SBP (1st year)	No	199	34	2.16	1.31–3.59 [d]	2.07	1.44–2.98 [c]	2.15	1.29–3.56 [d]
≥140 SBP (1st year)	Yes	39	9	2.95	1.39–6.28 [d]	1.97	1.07–3.64 [e]	2.92	1.37–6.22 [d]
Yes									
<140 SBP (1st year)	No	276	30	1.30	0.77–2.19	1.57	1.06–2.35 [e]	1.20	0.70–2.05
<140 SBP (1st year)	Yes	118	28	3.03	1.79–5.15 [c]	2.48	1.55–3.97 [c]	2.85	1.67–4.89 [c]
≥140 SBP (1st year)	No	187	33	2.23	1.34–3.71 [d]	1.98	1.29–3.04 [d]	2.09	1.24–3.51 [d]
≥140 SBP (1st year)	Yes	43	11	3.44	1.70–6.93 [c]	3.15	1.74–5.71 [c]	3.15	1.54–6.44 [d]
Physical workload exposure [g]									
No									
<140 SBP (1st year)	No	298	29	1		1		1	
<140 SBP (1st year)	Yes	85	16	2.04	1.11–3.76 [e]	1.55	0.81–2.95	2.02	1.09–3.71 [e]
≥140 SBP (1st year)	No	153	26	1.88	1.11–3.19 [e]	2.02	1.21–3.35 [d]	1.89	1.12–3.22 [e]
≥140 SBP (1st year)	Yes	26	4	1.63	0.57–4.63	2.42	1.12–5.20 [e]	1.64	0.58–4.66
Yes									
<140 SBP (1st year)	No	299	28	0.96	0.57–1.62	1.23	0.73–2.08	0.89	0.53–1.51
<140 SBP (1st year)	Yes	138	26	2.03	1.19–3.44 [d]	2.79	1.64–4.74 [c]	1.91	1.12–3.25 [e]
≥140 SBP (1st year)	No	233	41	1.90	1.18–3.05 [d]	2.15	1.29–3.57 [d]	1.79	1.10–2.89 [e]
≥140 SBP (1st year)	Yes	56	16	3.33	1.81–6.13 [c]	3.27	1.62–6.59 [c]	3.07	1.65–5.70 [c]
Follow-up until 1999									
Day work									
<140 SBP (1st year)	No	377	52	1		1		1	
<140 SBP (1st year)	Yes	136	36	2.12	1.38–3.24 [c]	1.43	0.85–2.42	2.05	1.34–3.15 [c]
≥140 SBP (1st year)	No	253	67	2.13	1.48–3.06 [c]	1.94	1.30–2.90 [d]	2.09	1.46–3.01 [c]
≥140 SBP (1st year)	Yes	47	13	2.30	1.25–4.23 [d]	1.96	1.03–3.75 [e]	2.28	1.24–4.18 [d]
Shift work									
<140 SBP (1st year)	No	220	45	1.55	1.04–2.31 [e]	1.34	0.90–1.99	1.41	0.93–2.14
<140 SBP (1st year)	Yes	87	26	2.43	1.52–3.90 [c]	2.61	1.70–4.00 [c]	2.28	1.41–3.67 [c]
≥140 SBP (1st year)	No	133	35	2.11	1.37–3.23 [c]	2.00	1.33–3.01 [c]	1.94	1.25–3.02 [d]
≥140 SBP (1st year)	Yes	35	14	3.59	1.99–6.48 [c]	2.86	1.59–5.14 [c]	3.28	1.80–5.98 [c]
Noise exposure [f]									
No									
<140 SBP (1st year)	No	321	44	1		1		1	
<140 SBP (1st year)	Yes	105	21	1.55	0.92–2.60	1.89	1.02–3.48 [e]	1.51	0.90–2.55
≥140 SBP (1st year)	No	199	53	2.14	1.43–3.18 [c]	1.76	1.04–2.99 [e]	2.12	1.42–3.16 [c]
≥140 SBP (1st year)	Yes	39	12	2.58	1.36–4.89 [d]	1.55	0.54–4.41	2.56	1.35–4.85 [d]
Yes									
<140 SBP (1st year)	No	276	53	1.43	0.96–2.13	0.93	0.55–1.56	1.34	0.88–2.03
<140 SBP (1st year)	Yes	118	41	2.90	1.90–4.44 [c]	1.93	1.14–3.28 [e]	2.77	1.79–4.26 [c]
≥140 SBP (1st year)	No	187	49	2.11	1.40–3.16 [c]	1.84	1.14–2.96 [e]	2.00	1.32–3.03 [d]
≥140 SBP (1st year)	Yes	43	15	3.06	1.71–5.51 [c]	2.88	1.55–5.33 [c]	2.86	1.58–5.20 [c]

(continued)

Table 3. Continued.

Time of follow-up	Elevated SBP [a]	N	CHD cases (N)	Unadjusted		Adjusted for age and smoking		Adjusted [b]	
				RR	95% CI	RR	95% CI	RR	95% CI
Physical workload exposure [g]									
No									
<140 SBP (1st year)	No	298	44	1		1		1	
<140 SBP (1st year)	Yes	85	20	1.75	1.03–2.96 [e]	1.57	0.93–2.67	1.73	1.02–2.93 [e]
≥140 SBP (1st year)	No	153	39	1.91	1.24–2.94 [d]	1.75	1.14–2.70 [e]	1.92	1.25–2.96 [d]
≥140 SBP (1st year)	Yes	26	5	1.39	0.55–3.50	1.27	0.5–3.210	1.39	0.55–3.51
Yes									
<140 SBP (1st year)	No	299	53	1.21	0.81–1.81	1.18	0.79–1.76	1.15	0.77–1.73
<140 SBP (1st year)	Yes	138	42	2.27	1.49–3.46 [c]	2.14	1.40–3.27 [c]	2.17	1.41–3.33 [c]
≥140 SBP (1st year)	No	233	63	1.99	1.36–2.93 [c]	1.91	1.30–2.81 [c]	1.91	1.29–2.82 [d]
≥140 SBP (1st year)	Yes	56	22	3.27	1.96–5.46 [c]	2.69	1.61–4.52 [c]	3.09	1.84–5.19 [c]

[a] SBP elevated if the mean level of the last year minus the mean level of the first year was >10.0 mmHg.
[b] Day–shift work adjusted for noise, noise and physical work load adjusted for day–shift work.
[c] P≤0.001.
[d] P≤0.01.
[e] P≤0.05.
[f] Noise exposure present if there was continuous or impulse noise.
[g] Physical workload exposure present when the product of the prevalence and level was in the second or third tertile.

Discussion

In our follow-up, we explored the change in SBP among workers exposed to shift work, noise and physical workload. We also studied the impact of baseline SBP and its increase on the risk of CHD due to these occupational exposures.

In our 8-year follow-up of the change in SBP, the most marked increase was found among those with a high physical workload—alone or in combination with shift work or noise or both. Moreover, the development of hypertension (in terms of SBP ≥140 mmHg) seemed to be a key factor in the pathway between physical workload and CHD in that, without hypertension, physical workload entailed no excess risk of CHD over the first 8 years and only a marginal risk had appeared by the end of the 12-year follow-up. By contrast, shift work entailed a significant risk even among normotensives when they were compared with normotensive day workers. In other words, if they also developed hypertension, their CHD risk was high, over fourfold that of the normotensive day workers. In the case of noise exposure, the findings were influenced by the two other exposures, shift work and physical workload, as only 2.7% of the workers were exposed to noise only.

Implications for comparisons with other studies

On the average, shift work did not entail a higher risk of SBP than day work in our study. However, had our study population been comprised primarily of 2-shift workers, a positive association would have been found, but, had 3-shift workers dominated, the association would have been negative. This difference between the two types of shift work was probably due to the difference in physical workload among the 2-shift and 3-shift workers in that physical workload was more common among the 2-shift workers than among the 3-shift workers. It is thus to be expected that findings depend on the populations studied. Indeed, there are also other studies with no or negative findings (16–20), but, on the other hand, several studies have found a positive association between shift work and hypertension (13–15). It seems that, even in the future, contrasting findings will continue to be reported until the most important concurrent exposures have been detected and included in the analyses. We have introduced one such factor, physical workload, to be considered together with shift work and noise exposure.

In our study, a greater physical workload clearly predicted an increase in SBP, and an increase was evident throughout the follow-up, the highest levels always being measured for workers in the third workload tertile. The influence of physical workload was also evident in respect to the SBP levels of the workers with different exposure combinations. While the mean SBP values of the shift work and noise group were generally below the means of the no exposure group, those of the physical workload and noise group and the physical workload and shiftwork group were constantly higher. We conclude that a dependence on concurrent exposures influences the findings.

Strengths and weaknesses of the study

There was a clear trial effect in all of the groups of workers with respect to intense health education in that a clear drop in the SBP levels of the groups occurred for 2–3 years. The phenomenon was similar in both arms of the trial. As the follow-up lasted 8 years, this phenomenon may have concealed a slight increase in the SBP levels. Gemfibrozil treatment as such did not influence the results, but the selection criteria for the trial ensured that our study population was more dyslipidemic than a normal population. However, at the first screening, the mean SBP level of the source population was 140.4 mmHg, and for our study cohort it was 141.4 mmHg. The selection thus had a modest effect on blood pressure. In addition, our study population consisted of employed middle-age men and was thus not a population-based sample.

There are pros and cons when a study population is divided into all possible combinations of three exposures. Although this division gave us the advantage of knowing exactly the exposures to which the participants were exposed, some of the groups were small (eg, 2.7% exposed to noise only), and there were many comparisons and tests. It is evident therefore that some of the P-values may have been due to chance. However, the main message of our study does not lie in the significance of separate values, but, instead, in the consistency of the overall findings.

Moreover, having used combined exposure groups, we were not able to compare our results properly to those of other studies in which only the effects of noise or the effects of shift work were studied. Boggild et al (27) found that shift work was commonly associated with other work environment factors shown to be related to CHD, and they raised the question of whether shift work could be acting as a proxy for other differences in the work environment. Indeed, in our study, less than 10% of the shift workers were exposed to shift work only, and the elevated levels of SBP among 2-shift workers could well be ascribed to concurrent exposure to physical workload.

The job status of the workers was recorded at the beginning of the CHD follow-up in our study, and we have no information about any change in jobs, transfers to day work or retirement during follow-up. However, because of the high mean age (45–60 years) at the beginning of the follow-up, we assumed that the cohort was a selected group and that early dropouts due to shift work would not occur. Most of the participants in the shift work groups (93.3%) reported at the beginning of the study that they had worked their shift work schedules for more than 5 years, and as many as 57.7% had done so for more than 20 years. Therefore, we were studying the long-term effects of these exposures rather than the short-term effects.

The information on exposure to noise or physical workload was obtained by linkage to the FINJEM and was, therefore, not obtained at the individual level as was the information about shift work, which came from the interview. The risks elicited through job-specific information tend to be lower than those based on person-specific information (35). The risks associated with exposures to noise or physical workload may thus have been underestimated.

We knew that, at the beginning of the follow-up, no one used antihypertensive medication, but we did not know whether any of the participants started such medication before the end point. This lack of information may have biased the results, probably by leveling out the differences. Along with noise exposure, noise-induced hearing loss and the use of personal hearing protection may also affect blood pressure (36–38). We did not know whether the workers in our study used any personal hearing protection or if they had noise-induced hearing loss.

The focus of our study was on the change in SBP with respect to a triad of hard occupational exposures. Apart from smoking, we did not take into account traditional lifestyle factors and other risk factors of CHD or psychosocial factors. The shift workers felt that they had less control over their jobs than did the day workers, while there were no differences in work demands and social support (22, 27, 39). According to Peter et al (40) job stress may partly mediate the effects of shift work on cardiovascular risk. Effect modification or confounding by psychosocial or lifestyle factors thus remains a possibility in our study.

Acknowledgments

The work of Hanna Virkkunen was conducted during the fellowship of the Doctoral Programs of Public Health with funding from the Ministry of Education. We also thank Virginia Mattila, Language Centre, University of Tampere, for her revision of the English language of the manuscript.

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Received for publication: 20 November 2006