Shiftwork and mortality from ischaemic heart disease

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Abstract

***Objectives*—To investigate the relation between shift work and death from ischaemic heart disease (IHD).**

***Methods*—A nested case-control approach was used. The cohort comprised male manual workers who joined an industrial company aged 50 years or under between 1 January 1950 and 31 December 1992 and worked there for at least one month. Cases were 467 cohort members who died during the same period aged 75 years or under, with ischaemic heart disease (IHD) (international classification of diseases (ICD) 410–414) coded from the death certificate. For each case a control worker was chosen, who joined the company at the same age and in the same period but who survived the case. Work status (shift work or day work) was assigned to cases for their entire employment and to controls for that part of their employment which preceded the matching case's death. The main source of information was historical personnel records containing pay codes which differed for day work and shift work. Information on weight, height, blood pressure, and smoking from a pre-employment medical was available.**

***Results*—Two thirds of subjects had been employed for at least one month as shift workers and there was evidence that they had slightly better health at recruitment than day workers. The odds ratio for shift workers during the period starting 10 years after shift work began, and after adjustment for height, body mass index, blood pressure, smoking, duration of employment, and job status (skilled or unskilled) was 0·90 (90% confidence interval (90% CI): 0·68–1·21). There was no relation between risk of IHD death, and duration of shift work, but there was evidence of a reduced risk when actively employed as a shift worker, together with an increased risk in the first five years after leaving shift work to do day work.**

***Conclusions*—Shift work did not increase the risk of death from ischaemic heart disease in this study. Those workers with poorer cardiovascular health may be under represented in groups with longer shift work experience because of health related selection out of shift work.**

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Evidence for the relation between shift work and cardiovascular disease has been reviewed in several articles,[1–5] with more recent reviews seeming to support an increased risk in shift workers. In 1978 Harrington[1] concluded that, from the limited evidence available, no excess cardiovascular morbidity or mortality had been found in shift workers. A review by Akerstedt and colleagues[2] in 1984 concluded that there was support, albeit weak, for an association. Five years later, Kristensen[3] suggested that 1·4 was the "most reasonable estimate" of relative risk. In 1992 Waterhouse and colleagues[4] considered that the evidence for a link was "becoming more difficult to dismiss as inconclusive". Finally in 1994, Harrington[5] stated that "the case for a link" was "strong enough to give serious consideration to such working practices being a causative factor".

To date, only one study has included death from cardiovascular disease as the main end point. From their historical cohort study, Taylor and Pocock[6] concluded that there was no relation between such deaths and shift work, although there was some evidence of an increased risk of death from arteriosclerotic disease in men under 60. They also found that men known to have transferred from shift work to day work within the companies surveyed had an increased rate of all cardiovascular deaths.

The main aim of the present study was to investigate the relation between death from ischaemic heart disease (ICD 410–414) and shift work. A secondary aim was to consider whether those who transferred from shift work to day work had an increased risk of such deaths.

Methods

SUBJECTS

A nested case-control approach was used. The study cohort was defined as all men who started work as industrial workers at the age of 50 years or under between 1 January 1950 and 31 December 1992 at a factory producing nuclear fuel elements and who worked there for at least one month. Work tasks associated with production were mainly to do with chemical processing and light engineering. Industrial workers as defined here comprised those directly involved in the production

process, manual skilled and unskilled workers who were indirectly associated with production (joiners, storemen), but not professional, technical, or administrative staff. Shift work was predominantly a three shift, one week, forward rotation system. There was no company policy on the selection of workers for shift work.

Under an existing agreement with the United Kingdom Office of Population, Censuses, and Surveys (OPCS), all deaths among study population members were notified to the company, together with cause of death as coded by OPCS from the death certificate. In this way the 467 cohort members who died from ischaemic heart disease (IHD) at age 75 years or under between January 1950 and 31 December 1992 were identified and formed the case group. For each case, a control worker who was alive at the time of the case's death was chosen from the cohort, matched as closely as possible on age and year of starting work at the site, with a maximum difference of three years being allowed on each variable. In the course of the study, 54 subjects were found to have started work in the 1940s, but were retained in the analyses.

SHIFT WORK INFORMATION

The aim was to ascertain for each case his work status (shift work or day work) on every day of his employment at the site. For controls, the relevant period of time was from the beginning of employment either to the end of employment or to the date of death of the matched case, whichever was the earlier.

Three sources of information on work status were available: personnel records, records of the dosimetry department which coordinated the issue of radiation film badges for the workforce, and occupational health department records. The most comprehensive shift work information came from personnel records. As wages for shift work and day work were on different pay scales, indicated by pay codes in personnel files, and pay codes nearly always included the start date and end date for the period to which they applied, work status for periods could be inferred when pay codes could be found. This information was considered to be of higher quality than information from other sources and, where available, was used in preference.

Occasionally, pay codes were known only at a point or points in time rather than for a period, for example on the first day of employment. A general rule for the use of point information was agreed: the status of the worker at the known point was assumed to continue unchanged for up to one year thereafter, provided no other information for that period existed.

The dosimetry department had recorded the status of employees (shift worker or day worker) when new film badges were issued. Dosimetry information was used when available to provide information on periods for which the pay codes were unknown. As this information was of the point type, it was used as described above.

Shift work status was not recorded routinely in occupational health files, but occasionally it was explicitly mentioned in the medical notes or could be inferred from visits to the department outside office hours. This information was also of the point type.

When no pay code, dosimetry information, or occupational health information on work status was available, the nature of the job or its location could sometimes be used to infer work status. Information on job title and location for each change of job within the company was available from personnel files. A company employee, who was familiar with work patterns at the site over the period, estimated work status from these data blind to whether the subject was a case or a control. Several arguments were used to justify these inferences, for example that the job was exclusively or predominantly a day (or shift) job or the location implied that day work (or shift work) was done. Where used, it was assumed that subjects continued in the same job or location until the next record of change.

In this study a shift worker is defined as someone who did shift work at the site for a period of one month or more. Other workers are referred to as day workers. Two subgroups of shift worker were distinguished: those who were still working shifts at the end of their employment (shift work stayers) and those who ended their employment doing day work (exshift workers). Among shift working controls, this classification described their last work status up to the time of death of their matched case.

Inspection of working patterns showed that many workers moved between shift work and day work and then back to shift work, with some having repeated changes between the two. Such movement might contribute to any negative effects of shift work or perhaps workers who changed frequently might have had an increased ability to tolerate shift work compared with others. The number of separate periods of shift work might therefore be important in determining effect. The total number of years spent in shift work was also calculated.

POTENTIAL CONFOUNDERS

Pre-employment medical examinations had been carried out routinely on all employees of the company. Height, blood pressure, and weight as recorded at these medicals were available for almost all study subjects. Body mass index (BMI) was calculated as weight (kg) divided by the square of height (m). Pre-employment smoking status was available for only 53% of subjects. The title of the first job was used to assign workers to one of three job status categories—skilled, unskilled, and semi-skilled.

Only pre-recruitment differences in blood pressure, BMI, and smoking were considered as potential confounding variables; adjustment for differences which may have developed during employment would be inappropriate if these changes were caused by shift work itself.

The possibility that those employed in shift

Table 1 Employment characteristics of 467 cases and 467 controls

	Cases	*Controls*
Age at start of employment (y):		
Mean	38·7	38·7
Median	39·9	39·7
SD	8·1	8·1
Range	16–50	16–50
Year of recruitment:		
Mean	1958	1958
Median	1958	1958
Range	1946–81	1946–81
Duration of employment (y):		
Mean	10·0	10·2
Median	7·1	8·0
SD	9·1	8·9
range	1mth–35yrs	1mth–35yrs
Age on leaving* (y):		
Mean	49·1	49·1
Median	50·0	50·6
SD	12·2	12·6
Range	21–65	17–66

*Some men were employed for two or more periods at the site and for them the total time from first employment to end of last employment at the site is longer than their duration of employment. Hence the mean age at leaving is slightly longer than the sum of the mean age at start and mean duration of employment.

work were fitter at recruitment than day workers was also considered by examining the relation between cardiovascular mortality risk and time since first starting shift work. Differences in mortality risk due to differential health related selection into groups are greatest immediately after selection and the difference declines as the time from selection increases.[7–9]

POWER

If a third (our initial estimate) of the study population were defined as shift workers, then the power of the study to detect an increased risk as measured by an odds ratio (OR) of 1·41, with a one sided test and a 5% significance level, is 80%. Further calculations with other estimates of the proportion who are shift workers showed that the size of the increased risk that can be detected with 80% power varied between 1·40 and 1·45 as the proportion in shift work varied between 0·33 and 0·67.

STATISTICAL ANALYSIS

Odds ratios were estimated with conditional logistic regression analysis. Although the paired structure of the data was accounted for in all analyses, the presentation of frequency distributions is for unpaired groups. Systolic and diastolic blood pressures, BMI, and height were used in logistic regression models as continuous variables after inspection of the categorical relations. Smoking was categorised as unknown, non-smoker, exsmoker, 1–9 a day, 10–19 a day, and > 20 a day and duration of employment as < 1 year, 1–2, 2–5, 5–10, 10–20 and > 20 years.

To minimise confounding, the main analyses of shift work included in the regression models the six variables already mentioned and also job status at the beginning of employment. Further, to allow for the possibility of health related selection into shift work, these analyses concentrated on those who survived at least 10 years after starting shift work. Tests for trend by duration of shift work and by other interval variables were based on regression coefficients for these factors used as continuous variables, with day workers (the zero level group) excluded.

Table 2 Coverage and source of work information

Coverage	*Source*	*Cases n (%)*	*Controls n (%)*	*Total n (%)*
Complete	Pay codes alone	343 (73)	333 (71)	676 (72)
Complete	Pay codes + other sources	71 (15)	88 (19)	159 (17)
Complete	Other sources only	51 (11)	45 (10)	98 (10)
Partial	Various	2 (0·4)	1 (0·2)	3 (0·3)
Total	All	467	467	934

Results

The median age at death of the cases was 63 years, with a range of 29–75 years; 21% (n = 100) died while still employed by the company, and 30% (n = 139) died more than 20 years after leaving.

Most cases began work at the site in the period 1950–69. The median age at the start of employment was 39 years and the median duration of employment was seven years. Fifteen per cent were employed for less than one year and 19% were employed 20 years or more.

Controls and cases were very similar for age at start of employment and year of recruitment (table 1), which reflects the matching carried on these variables. The median duration of employment among controls, censored at the date of death of the matching case where appropriate, was slightly longer (median eight years) than among cases.

In total, 21 315 years of observation were made on the 934 subjects (corresponding to a mean of 23 years per subject). Total years of employment at the site was 9423 (mean of 10 years per subject). Work status was assigned with pay code information for 81·3% of the total work-years, was inferred from other sources of information for 18·5%, and was unknown for 0·2%. When coverage was assessed at an individual level, 72% of subjects had complete histories from pay codes alone and all but three subjects had complete histories when other sources of information were included (table 2). The remaining three subjects had partial coverage and were treated in the analyses as though they were not employed during the missing time periods.

Two thirds of subjects (n = 631) were defined as shift workers. Eighty eight per cent started working shifts within a year of first employment at the site. Twenty per cent had only worked shifts, 39% ended their employment in shift work after at least one period of day work, and the rest (41%) were classified as exshift workers at the end of employment. The median (mean) years of shift work was 3·7 (6·8). Twenty per cent worked less than a year of shift work whereas 27% worked for more than 10 years.

Duration of employment seemed to be related to work status; among the controls for example, the median duration of employment was 9·1 years for shift workers compared with 4·3 for day workers, and there was a similar picture among cases. This divergence reflects the high proportion of day workers who were

Table 3 Work patterns among cases and controls

Type of work	Description	Cases n	Cases Years employed (median)	Cases Years shift work (median)	Controls n	Controls Years employed* (median)	Controls Years shift work (median)
Day worker	D	162	2·8	0	141	4·3	0
Shift worker:							
Stayer	S	59	1·9	1·9	66	2·3	2·3
Stayer	D → S	64	3·3	2·6	93	5·4	4·2
Stayer	... → S → D → S	46	15·5	10·7	42	16·9	13·9
Exshift	... → S → D → S → D	46	18·1	4·2	48	16·9	3·0
Exshift	D → S → D	50	10·8	1·7	44	14·2	2·0
Exshift	S → D	40	18·7	8·5	33	10·6	3·5
All		467			467		

S → D = worker started on shifts and ended on days; ... S → D means a period of work with status unspecified, then shift work, then ended on days.
*Employment coverage censored at date of death of matched case for 40 day worker and 77 shift worker controls.

employed for less than a year (26%) compared with shift workers (9%). However, within the shift work group, duration of employment also varied widely with pattern of employment (table 3).

ASSOCIATION BETWEEN CARDIOVASCULAR MORTALITY AND SHIFT WORK

Shift work was more common among controls (n = 326) than among cases (n = 305): OR (90% CI) of ever shift workers *v* day workers was 0·79 (0·62–1·01). There was a consistent pattern over time: the ORs for the three periods 1955–78, 1979–85, and 1986–92, in each of which a third of all deaths occurred, were all equal to 0·79. When analysis was restricted to the 180 deaths before the age of 60, the OR (90% CI) was 0·72 (0·49–1·04) compared with 0·85 (0·58–1·26) for deaths at the age of 60 or over.

An examination of differences in systolic and diastolic blood pressure and BMI between shift workers and day workers was carried out for the 443 pairs (95% of the total) with pre-employment information on these variables. Also compared were smoking status (known for 56% of these subjects), and two other indices, height and job status at entry, which might reflect social differences related to health.

Shift workers were less likely to have high blood pressure or to be overweight (table 4) but these differences are at least in part explained by their somewhat younger age at recruitment. Information on smoking status at recruitment was missing for a higher proportion of shift workers than day workers; this seemed to be because shift workers began employment earlier than day workers on average and information was more likely to be missing early on. The proportions in each group known to be smokers were the same but when the comparison was restricted to those whose smoking status was known, then smoking was slightly more common among shift workers. Shift workers were more likely to be in unskilled jobs although unskilled workers did not seem to have an excess risk in this study. When all six factors were included in the logistic model, together with duration of employment, the OR (90% CI) for all shift workers was increased to 0·85 (0·65–1·12).

There was a significantly reduced risk of death from IHD among shift workers in the first 10 years after shift work began, OR 0·42 (90% CI 0·21–0·84). During the next 10 years their relative risk was 0·94; thereafter there was no evidence of a trend in relative risk with increasing time from the start of shift work (table 5). Inclusion of the seven risk factors in this analysis did not alter the picture greatly. This pattern is consistent with a healthy shift worker effect which disappears 10 years after selection, which in turn suggests that a comparison which omits the first 10 years might be more valid. The OR for deaths from IHD among shift workers who survived at least 10 years from the time of first shift, when all seven risk factors were included in the model, was 0·90 (90% CI 0·68–1·21).

In the remaining analyses, ORs are given for both the crude (unadjusted) relations between shift work variables and risk, and for these relations when restricted to shift workers who survived at least 10 years from the time of first shift and adjusted for the seven risk factors.

Table 4 Differences at start of employment between shift workers and day workers (443 pairs with complete information on blood pressure, BMI)

	Controls Shift work (n = 308)	Controls Day work (n = 135)	Cases Shift work (n = 288)	Cases Day work (n = 155)
Age at recruitment (median y)	39·1	41·9	39·8	40·7
Height (median cm)	171	170	170	170
High blood pressure (% with systolic ⩾ 160 or diastolic ⩾ 95)	20	27	29	41
Overweight (% with BMI ⩾ 27)	14	17	17	22
Smoking (%):				
Unknown	48	39	44	39
Smoker	39	39	49	49
Non-smoker	13	22	7	12
Job status (% unskilled)	82	74	76	74

Table 5 Mortality from ischaemic heart disease by time since start of shift work

	Cases n	Controls n	Crude OR	*OR (90% CI) 7 indices included in model
Day workers	162	141	Baseline	
Shift workers (y since shift work began):				
0·1–9·9	22	33	0·42	0·51 (0·24–1·06)
10·0–19·9	82	82	0·94	0·97 (0·62–1·50)
20·0–29·9	127	134	0·83	0·81 (0·55–1·19)
⩾ 30·0	74	77	0·80	1·07 (0·57–2·02)
All workers	467	467		

*Regression model included the six risk factors described in table 4 (BMI, height, systolic BP, diastolic BP, job status, and cigarette consumption) and duration of employment.

Table 6 Mortality from ischaemic heart disease by duration of shift work

	Cases n	*Controls n*	*Crude OR*	**OR (90% CI) restricted to ⩾ 10 y follow up*
Day workers	162	141	Baseline	
Shift workers (y of shift work):				
0·1–1·9	120	117	0·87	0·95 (0·67–1·35)
2·0–4·9	51	60	0·71	0·98 (0·61–1·57)
5·0–9·9	53	60	0·72	0·89 (0·55–1·45)
⩾ 10·0	81	89	0·74	0·76 (0·50–1·17)
All workers	467	467		

*Regression model included the six risk factors described in table 4 (BMI, height, systolic BP, diastolic BP, job status, and cigarette consumption) and duration of employment.

Table 7 Mortality from ischaemic heart disease by age at start of shift work

	Cases n	*Controls n*	*Crude OR*	**OR (90% CI) restricted to ⩾ 10 y follow up*
Day workers	162	141	Baseline	
Shift workers (age at start):				
< 30	52	58	0·66	0·81 (0·42–1·55)
30–39	102	111	0·72	0·61 (0·38–1·00)
40–49	151	157	0·87	1·18 (0·79–1·74)
All workers	467	467		

*Regression model included the six risk factors described in table 4 (BMI, height, systolic BP, diastolic BP, job status, and cigarette consumption) and duration of employment.

Table 8 Mortality from ischaemic heart disease by number of separate periods of shift work

	Cases n	*Controls n*	*Crude OR*	**OR (90% CI) restricted to ⩾ 10 y follow up*
Day workers	162	141	Baseline	
Shift workers (no of shift work periods):				
1	213	236	0·76	0·88 (0·64–1·20)
2	60	66	0·77	0·79 (0·52–1·21)
⩾ 3	32	24	1·14	1·61 (0·91–2·86)
All workers	467	467		

*Regression model included the six risk factors described in table 4 (BMI, height, systolic BP, diastolic BP, job status, and cigarette consumption) and duration of employment.

There was no evidence of increasing risk with increasing duration of shift work (table 6). Rather, there was a suggestion that risk decreased with increasing years of shift work but a test for trend was not significant (P = 0·42), nor were any of the ORs significantly different from unity. The crude ORs increased with age at first start of shift work (table 7), but in the adjusted restricted analysis only the risk for men who started shift work at the age of 40 or after was greater than for day workers (OR 1·18, 95% CI 0·79–1·74). Those workers who had spent three or more separate periods in shift work seemed to have a somewhat higher risk than those who worked one or two separate periods only (table 8). The OR of 1·14 for this group rose to 1·61 (90% CI 0·91–2·86) when the analysis was adjusted for the seven risk factors and restricted to shift workers who survived 10 years or more. The increase of the risk ratio estimate after adjustment was primarily due to the effect of duration of employment; these workers were employed for longer than average (median 16 years) and long employment was generally associated with lower risk.

HEALTH RELATED SELECTION OUT OF SHIFT WORK

Forty one per cent (n = 261) of shift workers were classified as exshift workers at the end of their employment, whereas the rest were still doing shift work (shift work stayers). At recruitment those who were to become exshift workers did not differ greatly on the six prerecruitment risk factors from day workers or from those who were to become shift work stayers, tending to have values which were intermediate between these two groups. However, they tended to be employed for longer than stayers (table 3). Although employed for longer, they spent less time in shift work—the median duration being 2·9 years compared with 5·0 years in stayers.

The (adjusted, restricted) ORs (95% CIs) for shift work stayers and exshift workers compared with day workers were 0·80 (0·57–1·10) and 1·06 (0·75–1·49), respectively. In neither group was there a trend in risk by duration of shift work.

If movement out of shift work is related to cardiovascular health, then one would expect to see relatively fewer deaths from IHD when employed as a shift worker, with a corresponding excess of such deaths in the early years after shift work ends. This excess would diminish as the time from stopping shift work increased. To evaluate this, deaths among shift workers were categorised as occurring when employed as a shift worker and, for the exshift worker group, deaths occurring in the intervals 0·1–4·9, 5–9·9, 10–19·9, and ⩾ 20 years after the date of leaving shift work. Control shift workers were similarly classified at the time when follow up ended. Results are given both with and without omitting the first 10 years of shift work.

The ORs (90% CIs) for deaths from IHD when employed as a shift worker, unadjusted and adjusted for the seven risk indices, were 0·41 (0·25–0·67) and 0·48 (0·27–0·84), respectively. When the analysis was restricted to shift workers who survived at least 10 years

Table 9 Mortality from ischaemic heart disease by time since leaving shiftwork

	Cases n	*Controls n*	*Crude OR*	**OR (90% CI) without restriction*	*OR* (90% CI) restricted to ⩾ 10 y follow up*
Day workers	162	141	Baseline		
Shift workers:					
(i) Current	30	52	0·41	0·48 (0·27–0·84)	0·64 (0·33–1·22)
(ii) Exshift workers grouped by years since leaving shiftwork:					
0·1–4·9	14	6	1·98	2·69 (1·04–6·96)	2·89 (0·74–11·3)
5·0–9·9	15	20	0·57	0·56 (0·28–1·13)	0·66 (0·30–1·42)
10·0–19·9	56	50	0·92	1·09 (0·60–1·42)	1·15 (0·75–1·79)
⩾ 20·0	51	49	0·92	0·93 (0·58–1·48)	0·96 (0·60–1·53)

*Regression model included the six risk factors described in table 4 (BMI, height, systolic BP, diastolic BP, job status, and cigarette consumption) and duration of employment.

since shift work began, the OR for deaths among active shift workers was based on only 17 deaths and was no longer significant (0·64, 0·33–1·24). The crude and adjusted ORs (90% CIs) for exshift workers in the first five years after leaving shift work were 1·98 (0·87–4·51) and 2·69 (1·04–6·96), and when restricted to shift workers who survived at least 10 years since shift work began (nine deaths only), the OR (90% CI) was 2·89 (0·75–11·7). There was no excess of deaths beyond five years in exshift workers (table 9).

Discussion

In this study no excess risk of death from IHD, as coded from the death certificate, was found in shift workers compared with day workers. Two aspects of the study validity are important: the accuracy of exposure classification and the suitability of the day workers as a control group.

Retrospective classification of subjects as shift workers or day workers was based mainly on pay code information which should have been error free, although some clerical error cannot be ruled out. Information from other sources was probably less accurate; where pay codes and other information were available, discrepancies were occasionally found. Although some misclassification of workers is therefore possible, the overall quality of exposure information must be considered to be very good compared with most retrospective exposure assessment. As a further check, an analysis was carried out on the 253 pairs with complete information from pay codes on both members. The crude OR for those who had been shift workers for at least one month was 0·74 (compared with a value of 0·79 from the full data set).

Work status (shift or day) was known only for the period when a worker was employed at the factory (mean of 10 years per subject). As shift work is not uncommon, it is very possible that some of those classified as day workers (or shift workers) in this study were employed as shift workers elsewhere. If so, and if in reality shift work increased mortality rates, then the measured effect of shift work in this study may be biased towards the null value.

Were day workers in this study a suitable comparison group for shift workers? This concern was answered to some degree in the design of the study by restricting the cohort to those who began work as industrial workers. Nevertheless some differences between day workers and shift workers remained. The job at recruitment of day workers was more likely to be a skilled one (table 6), whereas shift workers were more likely to be involved in the less skilled work of chemical processing (68% *v* 48% of day workers). In fact there did not seem to be an association between skill level and risk in this study. There were no extremes of noise, heat, or cold associated with either day or shift work and organisation of work was similar for the two groups. Day workers were more likely to be employed for less than a year but additional analyses, not shown here, suggested that there was no increased risk in those with such short employment. In summary, no work exposure which might act to mask an association between shift work and mortality could be found.

Differences in known risk factors—that is, blood pressure levels and BMI as measured at recruitment—suggested that the shift worker group might be, at the start, slightly less likely to die from IHD, but the differences were small. These differences were accounted for, as far as is possible, through a regression model. Smoking data were incomplete but compatible with the suggestion that shift workers were slightly more likely to smoke than day workers.

There was a reduced risk of death from IHD in shift workers compared with day workers in the first 10 years after selection into shift work but no trend with time existed thereafter. In the case of health related selection into employment (the healthy worker selection effect), Fox and Collier[7] found that the effect on mortality had almost disappeared after 15 years of follow up although others[9] have suggested that this effect might persist for longer. In this study, the pattern of risk with time since shift work began might be explained by a healthy shift worker selection effect. If so, then an analysis which omits the early period of follow up will give a more valid measure of effect. This explanation was accepted and incorporated into the main analyses. Even if this interpretation is wrong, omission of the first 10 years in the present study would not have acted to disguise a harmful effect of shift work; rather it would have tended to disguise any beneficial effect.

Assuming that health related selection into shift work did explain the reduced risk early on, the OR (90% CI) of 0·90 (0·68–1·21) which has been adjusted for the seven risk factors and restricted to those shift workers with at least 10 years follow up, is considered as the best estimate of relative risk. On this evidence it seems reasonable to conclude that shift work did not increase the risk of death from IHD in this cohort.

To investigate the possibility of an exposure-response relation, duration of shift work was taken as the exposure measure: those in the highest category of exposure, 10 or more years, were found to have the lowest risk. However, assessment of the true dose-response relation is probably impossible if those with the highest exposure are in some sense a selected group; this would be the case if those shift workers who developed cardiovascular health problems leave shift work disproportionately. Such a phenomenon might be described as a healthy shift worker survivor effect.

The combination of a decreased risk of deaths from IHD when active as a shift worker (adjusted OR 0·48), and a higher risk within five years of transferring to day work (adjusted OR 2·69) suggests a health related survivor effect in the cohort. When the analyses are restricted to those who survived 10 years from first shift work, the ORs (0·64 and 2·89

respectively) are no longer significantly different from unity; nevertheless the pattern is maintained.

Although health related selection away from exposure may be a problem for the epidemiologist, it would be a positive move for the worker if it reduced the rate of progression from first symptoms to death. Workforces may differ in their abilities to make such moves within a company and this might explain any differences in the observed effects of shift work in different studies. Health surveillance in this company was carried out frequently with most workers attending an annual medical examination. Although there was no formal criterion for moving workers from shift work on health grounds, it was managerial practice during the period of the study to allow this on the advice of the occupational health service. However it seems implausible that such selection out of shift work was sufficiently precise to completely mask an important exposure-response relation between duration of shift work and risk of cardiovascular death.

The results here should be compared with those of the other mortality study[6] which found standardised mortality ratios (SMRs) for cardiovascular disease in male shift and day workers of 105 and 92 respectively (ratio of SMRs 1·15) and with studies of cardiovascular morbidity in male shift workers. In his review, Kristensen[3] considered three studies of sufficient quality to form a judgement. Of these, one[10] with only 43 events in total (myocardial infarction or angina) seemed to show a dose-response relation with an overall relative risk of 1·4. Duration of shift work was estimated retrospectively by the subjects or their relatives. In the other two studies of myocardial infarction with relative risks of 1·25[11] and 1·19[212] respectively, men were classified as shift workers if their occupational group (as coded at census) was estimated to have a high proportion of shift workers. Even had there been no misclassification of shift work in these studies, it could be argued that a comparison of shift workers with all other workers is not ideal.

It has been suggested that shift work might affect the cardiovascular system through disturbance of circadian rhythm, sleep, social life, stress, or by changes in the behaviour of the worker induced by shift work—such as increased smoking, alcohol intake, and poorer diet.[2 4 10 11 14] Some of these factors might be universally associated with shift work but others, for example, increased smoking, may be dependent on local conditions. It is worth noting that workers in this study were not allowed to smoke at the workplace.

In conclusion, in this study based on many cases, with precise estimation of shift work history and pre-employment information on blood pressure, smoking, and weight, no increased risk of mortality from ischaemic heart disease has been found (OR 0·90, 90% CI 0·68–1·21). In so far as extrapolation beyond this cohort to other shift workers is justified, a relative risk greater than 1·2 is unlikely.

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