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Mortality among a cohort of United Kingdom steel foundry workers with special reference to cancers of the stomach and lung, 1946-90

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Abstract

***Objective*—The aim was to describe cause specific mortality among steel foundry workers and to determine if any part of the experience may be due to occupation.**

***Design*—Historical prospective cohort study.**

***Setting*—Nine steel foundries in England and one in Scotland.**

***Subjects*—10 438 male production employees first employed in the period 1946-65 and with a minimum period of employment of one year.**

***Main outcome measures*—Observed and expected numbers of deaths for the period 1946-90.**

***Results*—Compared with the general population of England and Wales, standardised mortality ratios (SMRs) for all causes and all neoplasms were 115 (observed deaths (Obs) 3976) and 119 (Obs 1129) respectively. Statistically significant excesses were found for cancer of the stomach (Obs 124, expected deaths (Exp) 92·5, SMR 134, 95% confidence interval (95% CI) 111-160) and cancer of the lung (Obs 551, Exp 378·3, SMR 146, 95% CI 134-158). A raised SMR (153) was also found for non-malignant diseases of the respiratory system. Classifications of jobs attracting either higher dust or higher fume exposures did not usefully predict these increased SMRs. Poisson regression was used to investigate risks of mortality from all cancers, cancer of the stomach, cancer of the lung, and non-malignant diseases of the respiratory system associated with duration of employment in the foundry area, the fettling shop, the foundry area/fettling shop, and the industry in general. Monotonic dose-response relations were not found, although there were positive trends for lung cancer and employment in the foundry area/fettling shop (1·0, 1·21, 1·44, 1·26) and for diseases of the respiratory system and employment in the fettling shop (1·0, 1·37, 1·18, 1·35).**

***Conclusions*—Confident interpretation of the causes of the raised SMRs was not possible. There was limited evidence of an occupational role in the excesses of lung cancer and diseases of the respiratory system. Smoking history was shown, in an indirect way, to be an unlikely explanation.**

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The mortality experienced by a cohort of United Kingdom steel foundry workers for the period 1946-80 was investigated by Fletcher and Ades.[1] This report was included in the evaluation of the carcinogenic risk of working in iron and steel founding carried out by a working group of the International Agency for Research on Cancer (IARC).[2] This evaluation concluded "the available evidence indicates that occupational exposures occur in iron and steel founding which are probably carcinogenic to humans." Attempts to identify causative factors have, however, met with little success.[3]

A further analysis of the United Kingdom study relating to mortality from cancer in the period 1946-85 was reported by Sorahan and Cooke.[4] Raised SMRs were found for cancers of the stomach and lung and an analysis in which the employment histories of those dying from these diseases were compared with matching survivors from the cohort provided evidence of an occupational involvement in the risk of lung cancer from work in the foundry area/fettling shop and weaker evidence of an occupational involvement in the risk of stomach cancer from working in the foundry area. The analysis reported here includes deaths from a further five years of follow up.

Study population

The study population has been described elsewhere,[1] but may be summarised as all male operatives who started work in 10 steel foundries (nine English and one Scottish) between 1946 and 1965, and were employed for at least one year. Office staff and management were excluded. All foundries were members of the Steel Castings Research and Trade Association (SCRATA), which has provided financial and technical help at various times in the history of this study. (In 1993, SCRATA was incorporated within Castings Technology International (CTI).)

Detailed job histories—defined in terms of 25 categories[4]—were recorded for each employee. An independent assessment of those jobs attracting higher dust and fume exposures was available.[4] The mean number of jobs for members of the cohort was 1·7, the mean duration of employment was 9·3 years, and the mean period of follow up was 29·2 years.

Follow up procedures have also been described elsewhere.[1] Vital status was supplied by the National Health Service Central

Register (NHSCR). For those not traced at the NHSCR, vital status was sought from National Insurance records held by the Department of Social Security (DSS). For this reanalysis, the vital status of those members of the cohort classified as "flagged alive" was double checked with source records held at NHSCR. A few errors were found and appropriate corrective action was taken. Also, three members of the previous study cohort (n = 10 491) were excluded because identifying particulars had been lost, and 50 records were found to be duplicates (usually relating to two periods of employment carried out by the same worker). The analysis proceeded, therefore, on the basis of records for 10 438 workers.

Table 1 shows the vital status of the study population on the closing date of the study, 31 December 1990. For those known to have died, a death certificate was obtained with the cause of death coded to the 8th revision of the International Classification of Diseases (ICD-8).

Table 2 shows the study population by year of commencing employment and by year of leaving (final period of) employment. The table also provides annual numbers of deaths from all causes. Occupational histories are known to the end of 1983, at which time only 607 employees (6%) were still employed by the participating foundries.

The study population had originally included a further group of 625 workers with Indian, Pakistani, or Arab surnames. Overall mortality was found to be suspiciously low for this group (Obs 41, Exp 117·1, SMR 35). This finding probably represents inadequate tracing for these workers, and they have, therefore, been excluded from all analyses detailed in this report.

Table 2 Study population by year of commencing employment, year of leaving employment and employment state, and annual numbers of deaths from all causes

Year	*Commencing employment*	*Leaving employment*	*Still employed at end of year**	*Deaths from all causes†*
1946	501	0	501	0
1947	562	35	1028	0
1948	550	99	1479	1
1949	502	144	1837	4
1950	517	210	2144	5
1951	723	253	2614	10
1952	695	209	3100	16
1953	524	345	3279	22
1954	501	420	3342	17
1955	577	314	3623	27
1956	606	319	3910	20
1957	588	324	4174	32
1958	272	409	4037	36
1959	410	386	4061	34
1960	728	373	4416	36
1961	524	374	4566	43
1962	260	525	4301	45
1963	304	349	4256	67
1964	550	357	4451	73
1965	544	409	4586	62
1966	—	393	4193	92
1967	—	417	3777	91
1968	—	264	3513	90
1969	—	258	3255	95
1970	—	188	3067	107
1971	—	285	2783	100
1972	—	154	2629	120
1973	—	174	2455	125
1974	—	123	2332	122
1975	—	130	2202	147
1976	—	125	2077	128
1977	—	96	1981	121
1978	—	160	1821	142
1979	—	226	1595	157
1980	—	237	1360	154
1981	—	137	1223	169
1982	—	196	1027	181
1983	—	420	607	162
1984	—	—	—	158
1985	—	—	—	157
1986	—	—	—	202
1987	—	—	—	160
1988	—	—	—	162
1989	—	—	—	181
1990	—	—	—	158
Total	10438	9857		4031

*Employment state after 1983 is not known: use is only made of final period of employment for those who leave and re-enter employment.
†Includes deaths after 85 years of age.

Methods

EXTERNAL STANDARD

The mortality experience of this cohort was compared with that which might have been expected to occur if mortality for the general population of England and Wales had been operating on the study cohort, having due regard to the composition of the study cohort by age, sex, and calendar year.

Expectations based on person-years at risk were calculated with the PERSONYEARS computer program. Subjects entered the person-years at risk at the end of the first year of employment and left on the date of death, date of embarkation, date last known alive, or the closing date of the study, whichever was the earlier. Subjects were "censored" on reaching their 85th birthday—that is, they made no further contributions to expected or observed numbers past this age. The rationale for this procedure has been supplied previously.[4]

Table 1 Vital status at closing date of study (31 December 1990)

Vital status	*No (%)*
"Flagged" alive at NHSCR	5890 (56·4)
Traced alive at NI office	170 (1·6)
Emigrated	233 (2·2)
No trace	114 (1·1)
Died, cause known	4008 (38·5)
Died, cause unknown	23 (0·2)
Total	10438 (100·0)

Standardised mortality ratios (SMRs) were calculated as the ratio of observed to expected numbers of deaths expressed as a percentage. Where significance tests were carried out, two tailed tests were used. Tests for trend are those described by Breslow and Day.[5]

INTERNAL STANDARD: POISSON REGRESSION

Nine variables were considered to have the potential for influencing mortality within the cohort: attained age (age at follow up or age at death), calendar year, foundry (factory), employment state (still employed or left employment), period of follow up (years from first employment), duration of employment in the foundry area, duration of employment in the fettling shop, duration of employment in the foundry area/fettling shop, and duration of employment in the industry. These variables were not treated as continuous variables, but rather each variable was categorised into a number of levels. Employment history and employment state are time dependent variables and the analysis allowed, therefore, for subjects to contribute person-years at risk to contemporaneous categories. In these analyses those workers leaving employment before the end of 1983 change employment state from "still employed" to "left employment" three months after the date of leaving employment.

A suitable TRANS subroutine was written for the PERSONYEARS computer program to provide both person-years at risk and numbers of deaths for causes of interest for all combinations of all levels of all variables to be analysed. The output developed by this program was read directly by the GLIM computer program used to carry out statistical modelling by Poisson regression.[5] The purpose of the modelling was to establish whether the mortality of the study cohort, and in particular that of the different employment history groups, could be described easily in terms of variables such as attained age and calendar year (covariates), or whether the inclusion of employment history made a statistically significant contribution to the ability of the overall model to describe the data.

Results

EXTERNAL STANDARD

For successive 10 year periods from first employment, SMRs for all causes were 97, 123, 115, 121, and 92 respectively, based on 418, 1049, 1370, 1033, and 106 deaths. Corresponding SMRs for all cancers were 107, 136, 112, 119, and 117, and SMRS for all non-cancers were 94, 118, 116, 121, and 81. Although SMRs for these groupings were low in the 10 year period after first employment, general positive trends were not shown over the follow up period (trend statistics were not significant). There is, then, only limited evidence of a healthy worker effect[6] in these data.

Table 3 shows overall results both for mortality from cancer by site and for broad groupings of non-cancer causes of death. Compared with the general population of England and Wales, there were statistically significant excesses for cancer of the stomach (SMR 134), cancer of the lung (SMR 146), all cancers (SMR 119), diseases of the circulatory system (SMR 111), non-malignant diseases of the respiratory system (SMR 153), and all causes (SMR 115). There were statistically significant deficits for cancer of the brain (SMR 54) and suicide (SMR 66). These cancer findings are comparable with those supplied previously[4] to provide observed and expected numbers for the new period of follow up, 1986–90 (cancer of the stomach: Obs 18, Exp 15·1, SMR 119; cancer of the lung: Obs 110, Exp 79·1, SMR 139; all cancers: Obs 267, Exp 221·6, SMR 120; cancer of the brain: Obs 3, Exp 4·6, SMR 65).

Table 4 shows observed and expected numbers of deaths by first occupation for cancer of the stomach, cancer of the lung, and non-malignant diseases of the respiratory system. The excess for stomach cancer occurred predominantly in foundry area occupations, and, in particular, "furnace" and "furnace repair". The observed numbers of deaths for these last two categories, however, were as reported previously.[4] Raised SMRs for lung cancer were shown for a number of occupations although excesses were found predominantly in foundry area and fettling shop occupations, rather than pattern/machine/maintenance/inspection. Raised SMRs for diseases of the respiratory system were also shown for some occupations. The largest excess risk was for "fettling shop cranes" (SMR 345), and this was by contrast with findings for cancer of the lung relating to this occupation (SMR 87). Within the foundry area and fettling shop, the classifications of dust-exposed and fume-exposed jobs[4] were not predictors of raised SMRs and no further use of these classifications is made in this report.

Table 5 shows the observed and expected numbers of deaths by entry cohort and by period from first employment for the same three causes of death. For cancer of the stomach, similar SMRs were found for the four entry cohorts. In general, raised SMRs were found for the period 10–19 years from first employment and there were unexceptional SMRs for later periods of follow up. For the overall cohort, there was a statistically significant trend of SMRs decreasing with period of follow up ($p < 0·05$).

Table 3 Steel foundry workers: cancer mortality and mortality from other causes, 1946–90

Cause of death	*ICD-8*	*Obs*	*Exp*	*SMR (95% CI)*
Cancers:				
Lip	140	0	0·4	0 (0–979)
Tongue	141	4	3·1	129 (35–331)
Salivary	142	0	1·3	0 (0–296)
Mouth	143–145	3	2·9	102 (21–299)
Pharynx	146–149	6	6·4	93 (34–203)
Oesophagus	150	22	30·3	73 (45–110)
Stomach	151	124**	92·5	134 (111–160)
Small intestine	152	1	1·8	55 (1–304)
Large intestine	153	53	58·5	91 (68–119)
Rectum	154	50	41·9	119 (89–157)
Liver	155	5	6·9	72 (23–168)
Gall bladder	156	3	5·2	57 (12–167)
Pancreas	157	42	40·0	105 (76–142)
Peritoneum	158	2	2·0	99 (12–359)
Other digestive	159	4	2·4	169 (46–432)
Nose, sinuses	160	4	1·9	212 (58–542)
Larynx	161	12	9·0	133 (69–232)
Lung	162–163	551***	378·3	146 (134–158)
Bone	170	1	2·8	36 (1–198)
Skin	172–173	3	8·4	36 (7–105)
Breast	174	0	1·2	0 (0–312)
Prostate	185	42	49·6	85 (61–114)
Testis	186	3	3·2	93 (19–272)
Bladder	188	37	34·5	107 (76–148)
Other urinary	189	24	17·9	134 (86–200)
Brain	191–192	13[*]	24·0	54 (29– 93)
Thyroid	193	2	1·6	123 (15–443)
Lymphoma	200, 202	14	18·0	78 (43–131)
Hodgkin's	201	7	7·5	94 (38–193)
Multiple myeloma	203	9	10·7	84 (39–160)
Leukaemia	204–207	20	22·3	90 (55–138)
All cancers	140–239	1129***	948·4	119 (112–126)
Non-cancers:				
Dis Circulatory system	390–458	1852***	1671·5	111 (106–116)
Dis Respiratory system	460–519	588***	383·3	153 (141–166)
Dis Digestive system	520–577	79	91·1	87 (69–108)
Dis Genitourinary system	580–629	35	42·4	83 (58–115)
Dis Skin	680–709	1	1·6	63 (2–353)
Accidents	800–949	90	100·3	90 (72–110)
Suicide	950–959	30[*]	45·1	66 (45– 95)
All causes	1–999	3976***	3449·7	115 (112–119)

*$p < 0·05$; **$p < 0·01$; ***$p < 0·001$ (two tailed tests); [ ] indicates significant deficit.

Table 4 Steel foundry workers: mortality from stomach cancer, lung cancer, and non-malignant diseases of the respiratory system by first occupation, 1946–90

		Cancer of stomach			*Cancer of lung*			*Diseases of respiratory system*		
First occupation	*n*	*Obs*	*Exp*	*SMR*	*Obs*	*Exp*	*SMR*	*Obs*	*Exp*	*SMR*
Foundry area										
Sand preparation	132	2	1·5	131	5	6·4	78	12*	6·2	194
Moulding	1146	11	7·9	139	41	33·4	123	34	31·2	109
Furnace	556	11*	5·0	219	37**	20·9	177	28	19·9	141
Furnace repair	457	13**	4·3	302	28*	17·7	159	31**	17·2	180
Centrifugal casting	115	1	1·1	92	10*	4·3	232	8	4·4	182
Foundry cranes	299	3	2·6	115	16	11·2	143	11	10·3	107
Labourers etc	1369	16	15·1	106	100***	59·5	168	117***	66·6	176
Knockout	136	2	1·4	148	4	5·6	71	8	5·6	143
Other	68	3	0·9	335	5	3·2	155	5	4·3	115
All foundry area	4278	62**	39·8	156	246***	162·2	152	254***	165·8	153
Fettling shop										
Fettling	1035	9	8·2	110	63***	34·8	181	47**	30·9	152
Blasting	113	1	1·2	87	5	4·8	104	7	4·6	152
Burning and welding	401	1	2·6	39	19*	11·3	169	20**	9·2	218
Heat treatment	75	2	0·8	264	5	3·1	161	3	3·1	98
Fettling shop cranes	110	1	1·1	91	4	4·6	87	15***	4·4	345
Labourers etc	445	7	4·5	156	33***	17·9	185	46***	19·1	241
Other	87	1	0·9	106	7	3·9	181	4	4·0	101
All fettling shop	2266	22	19·2	115	136***	80·3	169	142***	75·2	189
Pattern/machine/maintenance/inspection										
Pattern making	319	1	1·4	74	7	5·7	122	5	5·0	99
Pattern shop labourer	77	3	1·0	316	3	3·7	81	5	4·6	110
Inspection	239	4	2·5	163	8	9·9	81	14	11·0	127
Machining	1268	11	8·0	138	46	34·2	135	31	29·6	105
Machine shop labourers	488	7	6·5	107	35*	23·9	147	66***	31·5	210
Welding	99	0	0·5	0	2	2·1	95	4	1·6	250
Maintenance	659	5	5·4	92	27	22·5	120	17	22·4	76
Maintenance mates	353	6	3·7	160	26*	15·2	171	27*	15·8	171
Other	392	3	4·7	64	15	18·7	80	23	21·0	109
All pattern/machine/ maintenance/inspection	3894	40	33·6	119	169**	135·9	124	192***	142·4	135

*p < 0·05; **p < 0·01; ***p < 0·001.

For cancer of the lung, similar SMRs were also found for the four entry cohorts. Trends of SMRs by period of follow up did not approach statistical significance. For diseases of the respiratory system, there were statistically significant trends of SMRs increasing with period of follow up both for the overall cohort ($p < 0·05$) and for the 1961–65 entry cohort ($p < 0·01$).

Table 5 Steel foundry workers: mortality from stomach cancer, lung cancer, and non-malignant diseases of the respiratory system by entry cohort and by years from first employment, 1946–90

	Entry cohort				
	1946–50	*1951–55*	*1956–60*	*1961–65*	*Total*
*Years from first employment**	*SMR (Obs)*	*SMR (Obs)*	*SMR (Obs)*	*SMR (Obs)*	*SMR (Obs)*
Cancer of stomach:					
1–9	227 (8)	86 (4)	164 (5)	83 (2)	140 (19)
10–19	151 (10)	215 (18)	216 (12)	166 (7)	190 (47)
20–29	120 (11)	129 (14)	84 (6)	82 (3)	110 (34)
30–39	108 (11)	105 (9)	104 (2)	—	107 (22)
⩾40	75 (2)	—	—	—	75 (2)
Total	131 (42)	139 (45)	141 (25)	117 (12)	134 (124)
Cancer of lung:					
1–9	104 (9)	119 (16)	163 (17)	119 (11)	127 (53)
10–19	126 (27)	153 (47)	194 (44)	147 (27)	155 (145)
20–29	121 (45)	153 (72)	165 (54)	169 (29)	149 (200)
30–39	133 (63)	165 (66)	98 (9)	—	143 (138)
⩾40	118 (15)	—	—	—	118 (15)
Total	125 (159)	153 (201)	165 (124)	149 (67)	146 (551)
Diseases of respiratory system:					
1–9	175 (22)	126 (21)	133 (15)	65 (6)	129 (64)
10–19	180 (48)	120 (42)	113 (25)	132 (22)	136 (137)
20–29	178 (71)	155 (75)	136 (40)	226 (32)	165 (218)
30–39	172 (75)	146 (56)	234 (18)	—	166 (149)
⩾40	170 (20)	—	—	—	170 (20)
Total	176 (236)	140 (194)	139 (98)	150 (60)	153 (588)

*Irrespective of how long any worker remains in the industry.

INTERNAL STANDARD

On the basis of prior considerations and the results already described, cancer of the stomach, cancer of the lung, and non-malignant diseases of the respiratory system were selected as causes of death of primary interest for further study. It was unlikely that occupational exposure would discernibly influence general mortality, and mortality from all causes was also studied, to assess the usefulness of the explanatory variables.

Table 6 provides relative risks by levels of four employment histories (16 separate analyses) in which employment history was analysed simultaneously with attained age, calendar year, period of follow up, employment state, and foundry. (In constructing the models, levels were combined to ensure that, for each variable, at least one death was observed in each level as entered into the analysis.) The inclusion of employment history into the overall model made a statistically significant improvement to the model for four of the 16 analyses (duration of employment in the fettling shop and mortality from all causes and from diseases of the respiratory system; duration of employment in the foundry area/fettling shop, and mortality from all causes and from lung cancer).

Table 6 also shows, under the heading "trend", estimates of relative risk per unit change in level of employment history. These relatives risks were obtained from a further 16 separate analyses in which the four levels of employment history were treated as a continuous variable (coded 1 to 4). The largest

Table 6 Relative risks by employment history (16 separate analyses) obtained from a multiplicative model and analysed simultaneously with attained age, calendar year, period of follow up, employment state, and foundry

Exposure level	*All causes*			*Cancer of stomach‡*			*Cancer of lung§*			*Diseases of respiratory system‖*		
	n†	*RR*	*(95% CI)*	*n*	*RR*	*(95% CI)*	*n*	*RR*	*(95% CI)*	*n*	*RR*	*(95% CI)*
Duration of employment in foundry area (y)												
None	2157	1·0	—	59	1·0	—	288	1·0	—	318	1·0	—
>0·0	968	0·98	(0·91–1·06)	38	1·39	(0·92–2·11)	137	1·06	(0·86–1·30)	148	1·00	(0·82–1·22)
5·0−	548	1·03	(0·94–1·14)	21	1·45	(0·88-2·40)	80	1·14	(0·89-1·46)	80	0·95	(0·74–1·22)
⩾15·0	303	1·07	(0·94–1·21)	6	0·99	(0·42–2·33)	46	1·12	(0·81–1·54)	21	0·95	(0·69–1·33)
Trend¶		1·02	(0·98–1·05)		1·12	(0·93–1·35)		1·05	(0·96–1·15)		0·98	(0·90–1·07)
Duration of employment in fettling shop (y)												
None	2976	1·0	—	99	1·0	—	406	1·0	—	431	1·0	—
>0·0	483	1·10	(0·99–1·21)	13	0·87	(0·49–1·58)	65	1·11	(0·85–1·45)	77	1·37*	(1·07–1·76)
5·0−	3114	1·22***	(1·08-1·37)	7	0·80	(0·37-1·74)	47	1·32	(0·97-1·79)	43	1·18	(0·86-1·62)
⩾15·0	203	1·05	(0·90–1·21)	5	0·99	(0·39–2·49)	33	1·11	(0·77–1·61)	37	1·35	(0·95–1·92)
Trend		1·05**	(1·01–1·09)		0·94	(0·74–1·20)		1·08	(0·98–1·19)		1·12*	(1·02–1·23)
Duration of employment in foundry area/fettling shop (y)												
None	1291	1·0	—	37	1·0	—	157	1·0	—	182	1·0	—
>0·0	1319	1·04	(0·96–1·13)	48	1·31	(0·84–2·04)	185	1·21	(0·98–1·51)	201	1·16	(0·94–1·42)
5·0−	843	1·15**	(1·05-1·26)	28	1·34	(0·81-2·20)	129	1·44**	(1·13-1·82)	125	1·18	(0·94-1·49)
⩾15·0	523	1·11	(0·99–1·23)	11	1·04	(0·52–2·12)	80	1·26	(0·95–1·67)	80	1·17	(0·89–1·54)
Trend		1·05**	(1·01–1·08)		1·07	(0·89–1·29)		1·11*	(1·02–1·21)		1·06	(0·98–1·15)
Duration of employment in industry (y)												
0·0−	1828	1·0	—	65	1·0	—	244	1·0	—	277	1·0	—
5·0−	766	1·04	(0·96–1·14)	24	0·91	(0·50–1·47)	105	1·08	(0·86–1·37)	118	0·97	(0·78–1·21)
10·0−	520	1·11	(1·00–1·23)	16	0·92	(0·51–1·67)	80	1·26	(0·96–1·65)	69	0·86	(0·66–1·14)
⩾15·0	862	1·08	(0·99–1·19)	19	0·85	(0·47–1·53)	122	1·03	(0·80–1·33)	124	0·94	(0·74–1·19)
Trend		1·03*	(1·00–1·06)		0·95	(0·79–1·14)		1·03	(0·95–1·11)		0·97	(0·90–1·05)

*p < 0·05; **p < 0·01; ***p < 0·001.
†Number of deaths. ‡ICD-8, 151. §ICD-8, 162-3. ‖ ICD-8, 460-519. ¶ see text.

relative risks are shown for analyses of (1) cancer of the stomach and foundry area employment, (2) cancer of the lung and employment in the foundry area/fettling shop, and (3) diseases of the respiratory system and employment in the fettling shop, although only the last two risks were statistically significant.

The stability of the relative risks derived from the three analyses may be assessed by comparison with risks derived from sparser models (see table 7). The full model presented in table 6 is model 5. Associations with employment history were stronger in the full model, although, in general, differences were modest.

Table 7 Relative risks for levels of employment history variables after simultaneous adjustment for various combinations of other variables

Exposure level	Model 1 RR	Model 2 RR	Model 3 RR	Model 4 RR	Model 5 RR
Cancer of stomach and duration of employment in foundry area					
None	1·0	1·0	1·0	1·0	1·0
>0·0	1·46	1·48	1·47	1·44	1·39
5·0-	1·47	1·56	1·56	1·48	1·45
⩾15·0	0·70	0·80	0·81	1·01	0·99
Trend†	1·05	1·09	1·09	1·13	1·12
Disease of respiratory system and duration of employment in fettling shop					
None	1·0	1·0	1·0	1·0	1·0
>0·0	1·32	1·36	1·35	1·36	1·37
5·0-	1·18	1·16	1·17	1·17	1·18
⩾15·0	1·15	1·13	1·14	1·30	1·35
Trend	1·08	1·07	1·08	1·11	1·12
Cancer of lung and duration of employment in foundry area/fettling shop					
None	1·0	1·0	1·0	1·0	1·0
>0·0	1·24	1·23	1·21	1·21	1·21
5·0-	1·43	1·44	1·44	1·43	1·44
⩾15·0	1·19	1·21	1·21	1·27	1·26
Trend	1·09	1·09	1·10	1·11	1·11

*Model 1: attained age, employment history; model 2: attained age, employment history, foundry; model 3: attained age, employment history, foundry, employment state; model 4: attained age, employment history, foundry, employment states, period of follow up; model 5: attained age, employment history, foundry, employment state, period of follow up, calendar year.
†See text.

Table 8 shows the relative risks for levels of period of follow up, calendar year, foundry, and employment state (simultaneous analysis summarised in table 6) for three analyses. As expected, in service death rates were lower than corresponding rates among leavers. There were pronounced differences in mortality between foundries, both for lung cancer and for diseases of the respiratory system. Also, there were pronounced negative trends for mortality by calendar year; these trends relate, of course, to absolute risks and not to relative mortality patterns as described by SMRs.

All analyses summarised in table 6 were repeated with the four employment history variables lagged by 10 years. By definition, deaths occurring in the 10 year period after first employment were uninformative and were ignored. Findings were not very different from those displayed in table 6. Monotonic dose-response effects were not found.

Discussion

The main purpose of this analysis was to carry out a further assessment of the likely involvement of occupational exposures in the raised SMRs known to exist for this cohort, both for cancer of the stomach and cancer of the lung, and to consider whether such exposures are a risk factor for non-malignant diseases of the respiratory system. The new findings are disappointing from the point of view of facilitating a confident interpretation. For example, there were a number of dramatically raised SMRs for lung cancer but clear trends were not seen for SMRs either by year of hire (even though general working conditions were much better for the 1961–5 entrants than for the 1946–50 entrants) or by period of follow up (occupa-

Table 8 Relative risks for three separate analyses obtained from a multiplicative model and analysed simultaneously with attained age*

	All causes and duration of employment in foundry area/fettling shop			*Cancer of lung and duration of employment in foundry area/fettling shop*			*Diseases of the respiratory system and duration of employment in fettling shop*		
	n	*RR*	*(95% CI)*	*n*	*RR*	*(95% CI)*	*n*	*RR*	*(95% CI)*
Follow up period:									
1–9	418	1·0	—	53	1·0	—	64	1·0	—
10–19	1049	1·14	(0·99–1·32)	145	1·03	(0·70–1·53)	137	1·14	(0·77–1·69)
20–29	1370	1·03	(0·87–1·22)	200	0·94	(0·60–1·48)	218	1·51	(0·96–2·38)
30–39	1033	1·08	(0·89–1·31)	138	0·92	(0·56–1·52)	149	1·43	(0·86–2·38)
⩾40	106	0·83	(0·63–1·09	15	0·82	(0·39–1·69)	20	1·41	(0·71–2·79)
Calendar year:									
1946–55	102	1·0	—	12	1·0	—	19	1·0	—
1956–60	158	0·69	(0·54–0·89)	14	0·53	(0·25–1·16)	28	0·62	(0·34–1·12)
1961–65	292	0·67	(0·52–0·85)	37	0·77	(0·38–1·54)	43	0·45	(0·25–0·83)
1966–70	474	0·69	(0·54–0·88)	71	0·97	(0·49–1·93)	80	0·45	(0·25–0·83)
1971–75	608	0·66	(0·51–0·85)	85	0·87	(0·43–1·78)	85	0·29	(0·15–0·55)
1976–80	690	0·58	(0·45–0·75)	99	0·82	(0·39–1·70)	94	0·22	(0·11–0·42)
1981–85	815	0·55	(0·42–0·72)	124	0·88	(0·42–1·85)	113	0·19	(0·10–0·37)
1986–90	837	0·51	(0·39–0·67)	109	0·72	(0·34–1·54)	126	0·17	(0·08–0·34)
Foundry:									
1	369	1·0	—	62	1·0	—	59	1·0	—
2	459	0·95	(0·83–1·09)	82	0·97	(0·70–1·35)	59	0·78	(0·54–1·12)
3	118	0·84	(0·68–1·04)	16	0·67	(0·39–1·16)	19	0·83	(0·49–1·39)
4	139	0·70	(0·58–0·85)	10	0·30	(0·15–0·57)	16	0·53	(0·31–0·93)
5	870	1·02	(0·90–1·15)	136	0·88	(0·65–1·20)	154	1·23	(0·90–1·66)
6	209	0·92	(0·77–1·09)	23	0·56	(0·34–0·90)	32	0·84	(0·54–1·31)
7	374	0·87	(0·75–1·01)	50	0·65	(0·45–0·95)	44	0·71	(0·48–1·06)
8	272	0·91	(0·78–1·06)	30	0·59	(0·38–0·91)	45	0·97	(0·66–1·43)
9	877	1·03	(0·91–1·16)	108	0·75	(0·55–1·02)	140	1·04	(0·77–1·41)
10	289	1·03	(0·88–1·20)	34	0·72	(0·47–1·09)	20	0·47	(0·28–0·79)
Employment state:									
Left	3442	1·0	—	463	1·0	—	517	1·0	—
Still employed	534	0·67	(0·60–0·74)	88	0·88	(0·67–1·16)	71	0·70	(0·52–0·94)
Duration of specified employment history:									
None	1291	1·0	—	157	1·0	—	431	1·0	—
>0·0	1319	1·04	(0·96–1·13)	185	1·21	(0·98–1·51)	77	1·37	(1·07–1·76)
5·0-	843	1·15	(1·05–1·20)	129	1·44	(1·13-1·82)	43	1·18	(0·86-1·62)
⩾15·0	523	1·11	(0·99–1·23)	80	1·26	(0·95–1·67)	37	1·35	(0·95–1·92)

*These analyses are summarised in table 6.

tional cancers would be expected to occur in later periods of follow up). The internal analyses provided some evidence of an occupational involvement in lung cancer mortality from work in the foundry area/fettling shop and in mortality from non-malignant diseases of the respiratory system from work in the fettling shop, although clearcut dose-response effects were not found. For example, it was not surprising to find, given that the SMR for lung cancer was 152 among those first employed in the foundry area, 169 among those first employed in the fettling shop, and only 124 among those first employed in pattern/machine/maintenance/inspection, that relative risks for lung cancer associated with the three exposed levels (>0·0, 5·0–14·9, ⩾15·0 years) of duration of employment in the foundry area/fettling shop were all higher than the risk associated with the unexposed level (none). This analysis could only provide convincing additional information of an occupational effect if there was .a positive trend across the exposed levels themselves. All the internal analyses failed to identify such an effect.

These data have limitations. Data on smoking histories were not available, although there is no good reason to believe that they would be correlated with the employment history variables analysed in this study. A generally increased prevalence of cigarette smoking within this cohort, however, compared with the national average could, of course, explain some or all of the increased respiratory disease risks (malignant and non-malignant). Andjelkovich *et al* postulated such an explanation for the homogeneity of increased risks of lung cancer in their study of United States iron foundry workers.[7] Such an explanation is unlikely to apply to the study reported here because overall findings for cancers considered by others to be related to cigarette smoking (tongue, mouth, pharynx, oesophagus, pancreas, larynx, bladder and other urinary)[8] were close to expectation (Obs 150, Exp 144·1, SMR 104). Of more concern, data on employment history both before and after employment for the 10 participating foundries were also unavailable. If foundry workers in this study tended to work in other foundries for other parts of their working life then this would limit the potential of observing dose-response effects within the study cohort. Some evidence of such a tendency was found from a review of 311 death certificates relating to employees who both left the employment of the participating foundries aged 35 years or less and died aged 55 years or more. It is likely that most of these men moved to other jobs in the interim period. Some 13% of the jobs detailed on the death certificates related clearly to work in the iron or steel industry, and a further 26% may have related to these industries.

A detailed historical assessment of work processes, practices, and conditions at each of the 10 participating foundries could usefully be incorporated into further analyses. Such an assessment might lead to an explanation for the significant interfoundry variation in respiratory disease risks, and this would be more useful than, say, extending the period of follow up for a further five years. Consideration would have to be given to the composition of binders and to the other products used in foundries. Formulations change over the years and in a retrospective survey important items could easily be missed if only a few individual components were assessed. Until more definitive data become available on relations between exposure of foundry workers to individual chemicals and increased risks of cancer, efforts in foundries are probably better directed to the total control of fume and dust.

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2 Soter NA, Wasserman SI, Austen KF. Cold urticaria: release into the circulation of histamine and eosinophil chemotactic factor of anaphylaxis during cold challenge. *N Engl J Med* 1976;**294**:687–90.
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