Respiratory disease mortality patterns among South African iron moulders

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ABSTRACT To assess the influence of foundry exposure on malignant and non-malignant respiratory disease, the proportional mortality ratio (PMR) was used to compare the cause of death distributions of the 578 dead members of the Iron Moulders Society of South Africa, recipients of the union's death benefit fund between 1961 and 1983. Comparisons were made with the age and period specific white male deaths. For the 419 members where job information was available, the influence of occupation (journeyman, production moulder) was assessed using different techniques—the relative proportional mortality ratio (RPMR), the mortality odds ratio (MOR), and the proportional cancer mortality ratio (PCMR) for comparison. Excess PMRs were found for cancer of the trachea, bronchus, and lung (1.71, $p = 0.03$; Poisson one sided test) for those over 65 and for non-malignant respiratory disease (1.58, $p = 0.01$) and for injuries and poisonings (2.61, $p < 0.0001$) in those under 65. Reduced PMRs were found for all cancers (0.75, $p = 0.03$) and all circulatory disease (0.91, $p = 0.12$) in those under 65. When comparing job types, raised risks were obtained for journeymen using all methods (RPMR, MOR, PCMR) but the small cell sizes rendered the results non-significant. The raised PMRs due to respiratory disease are unlikely to be due to smoking because of a poor association with other causes of death related to smoking. A more likely explanation is that these excess rates for malignant and non-malignant respiratory disease are due to exposure to the foundry environment. Of additional concern are the high PMRs due to injuries and poisonings, which could be related to the high accident rates in the iron and steel industry.

Epidemiological evidence concerning the positive association between foundry exposure and respiratory disease (malignant and non-malignant) has been accumulating since the first studies conducted some 50 years ago. Of particular concern are silica and other particulate dusts and suspected carcinogens such as polycyclic aromatic hydrocarbons and benzo(a)pyrenes, both commonly found in foundries.^{1,2} The association between exposure to these compounds and respiratory and other diseases has been reviewed extensively elsewhere.²⁻⁴

In countries where detailed statistical and employment records are kept the standardised mortality ratio (SMR) has been the method of choice, using national or local rates to derive the expected age

cause specific comparison rates. When there is no available information on the population at risk—for instance, the records of death benefit funds—use may be made of the proportional mortality ratio (PMR) as an approximation to the SMR.⁵ A recent development in occupational disease mortality studies has been to treat the data as a variant of a case-control study, using the relative PMR, the mortality odds ratio (MOR), and proportional cancer mortality ratio (PCMR) instead of the PMR approach.⁶⁻⁸ Several studies concerning foundry and other occupational exposures have been conducted using these methods.⁹⁻¹²

The availability of the records of a death benefit fund of a predominantly white closed shop craft union, the Iron Moulders Society of South Africa (IMS-SA), presented the opportunity to compare the PMR, MOR, and PCMR in order to assess the effect of type of job on malignant and non-malignant respiratory and other causes of death.

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Subjects

UNION RECORDS

The IMS-SA was established in 1896 and currently has about 3000 members. Originally it drew on immigrant Europeans and Afrikaners. Changes in production volumes, production methods, and demands for cheaper non-white labour led to the introduction of "coloured" members (workers of mixed racial backgrounds) into the industry during the second world war and subsequently into the union in 1945. In a similar fashion black workers were introduced to moulding in the 1950s and were incorporated into the union in 1979.^{13,14} The IMS-SA death benefit fund was set up in 1961 to provide funeral and other death benefits for members and their widows. Benefits applied to those who had been members for over one year. After ten years' membership members may leave the trade but still continue to contribute to the death benefit fund and be eligible for benefits. Members joined up for an apprenticeship period of six years (now reduced to four) in order to become skilled journeymen. Journeymen are engaged primarily in designing and constructing moulds. Production moulders do not have to undergo any apprenticeship and are primarily engaged in manufacturing moulds from preformed patterns. Both are engaged in hot and cold jobs and journeymen are more likely to become supervisors of moulding operations. Altogether 630 deaths were recorded in the minutes of the death benefit fund. Full names and all other available details were sent to the Department of the Interior which returned the death certificates containing the International Classification of Disease Code for the underlying cause of death. Twenty six of the deaths were of non-white members. Because of low numbers and poor population comparison information for non-white South Africans, they were excluded from the study. Two members out of benefit and one female member were also excluded. No full follow up was conducted to assess those who died out of benefit.

Union records included information on job type (journeyman (JM), production moulder (PM), 72.2% complete), date of birth (100% complete) and year of death (100% complete), which allowed for stratification by age at death, year of death, and by job type.

Methods

PROPORTIONAL MORTALITY ANALYSIS

Expected proportions of cause specific deaths were calculated from the South African national death records for each year, from 1961 to 1983 using the person-years computer program.¹⁶ Results for each cause of death of interest from each five year age at death interval (20–24, 25–29...≥65) were

accumulated. The expected deaths were calculated from the proportion of all deaths in a particular age and calendar year stratum due to the cause of death of interest in the South African population multiplied by the number of deaths from all causes in the same age and calendar year stratum in the iron moulders. The three changes in the ICD codes during 1961–83 (6th, 7th, 8th revisions) were incorporated into the program. A summary PMR for each cause of death of interest was produced by dividing the number of deaths for a particular cause by the expected number of deaths derived as previously mentioned. A Poisson one sided test of significance value was calculated. Results were stratified by age at death (<65, ≥65, $n = 578$) and job type and age at death (journeymen < 65, ≥65; production moulders, < 65, ≥65, $n = 419$).

RPMR, MOR, AND PCMR ANALYSES

The RPMR was calculated by comparing the proportion of deaths due to the cause of interest in one exposure category to the proportion of deaths of interest in the other category. The MOR uses the non-cases unrelated to exposure risk as controls.⁷ For example, in lung cancer deaths due to non-malignant respiratory disease were excluded from the control group. In respiratory disease comparisons deaths from lung cancer were excluded from the control group. To assess the effect of these exclusions the MOR used two different control groups: (i) all non-cases and (ii) all non-cases without the "other" respiratory diseases of interest. In the PCMR analysis all non-cancer deaths were excluded.⁸ In this study, where respiratory disease comparisons are made, lung cancer was excluded from the control groups. In all instances two by two tables were constructed from the PMR results for journeymen and production moulders to determine the odds ratio (OR) between malignant or non-malignant respiratory disease and odds of job type exposure. Analysis was stratified into two age at death intervals, 20–64 and ≥65 years. Small cell sizes necessitated the use of Fisher's exact test (2 sided).¹⁷ Where the expected cell frequency exceeded 5 in all cells the chi-squared test (1 df) with a continuity correction was used.

Results

PMR ANALYSIS

Tables 1–3 give the observed and expected numbers of deaths for the causes of death of interest with the O/E ratio and Poisson one sided p values. Table 1 is stratified by age alone, whereas tables 2 and 3 are stratified by age and job type.

Table 1 Results of the PMR analysis: (1) stratified by age

Cause	Age (years)							
	20-64 (n = 372)				≥65 (n = 206)			
	Obs	Exp	O/E	Poisson 1 sided p*	Obs	Exp	O/E	Poisson 1 sided p*
All cancer	40	53.7	0.75	0.03	33	36.12	0.91	0.34
Ca buccal, lip, pharynx	3	2.26	1.33	0.39	0	1.05	—	—
Ca larynx	2	1.22	1.64	0.35	0	0.55	—	—
Ca trachea, bronchus, lung	13	15.48	0.84	0.31	15	8.75	1.71	0.03
Ca oesophagus	3	1.78	1.69	0.26	1	1.13	0.89	0.69
Ca stomach	5	5.51	0.91	0.52	3	4.71	0.64	0.31
Ca intestines, rectum	1	4.26	0.24	0.07	2	3.53	0.57	0.32
Ca prostate	1	1.48	0.68	0.56	5	5.64	0.89	0.51
All non-malignant respiratory	39	24.7	1.58	0.005	34	28.1	1.21	0.15
Respiratory tuberculosis	4	2.05	1.95	0.15	3	0.75	3.98	0.04
All circulatory	152	167.43	0.91	0.12	98	109.9	0.89	0.14
All poisonings, accidents	78	29.91	2.61	0.000	7	8.87	0.79	0.34

*In the direction of the observed value.

CANCER OF THE TRACHEA, BRONCHUS, AND LUNG (ICD 162-166)

An increased PMR for malignant respiratory disease was found for the older iron moulders (aged over 65) (O/E = 1.71, p = 0.03) and a decreased PMR among the younger iron moulders (under 65) (O/E = 0.84, p = 0.31). When stratified by job type and age at death, raised PMRs were found for both older journeymen and production moulders (journeymen < 65 O/E = 1.14, p = 0.38; journeymen ≥65 O/E = 1.94, p = 0.025; production moulders ≥65 O/E = 1.62, p = 0.46). Young production moulders had a reduced PMR (O/E = 0.87, p = 0.59).

NON-MALIGNANT RESPIRATORY DISEASE (ICD 460-519.9)

Excess PMRs for non-malignant respiratory disease were found for all stratifications except for the older

production moulders (≥65 O/E = 0.51, p = 0.41). Stratified by age alone, O/E values for those under 65 were 1.58 (p = 0.005) and 1.21 (p = 0.15) for those over 65. Stratified by job type PMRs were as follows: journeymen < 65 O/E = 1.66, p = 0.02; journeymen ≥65 O/E = 1.35, p = 0.08; production moulders < 65 O/E = 1.76, p = 0.11.

OTHER CAUSES OF DEATH

Injury and poisoning (ICD 800-999)

Significantly raised PMRs for injuries and poisonings were observed for all younger categories. For those under 65 O/E = 2.61, p < 0.0001. For journeymen < 65 O/E = 3.38 (p < 0.0001) and for production moulders < 65 O/E = 5.94 (p < 0.0001).

Circulatory disease (ICD 390-459.9)

All stratification levels except that for the younger

Table 2 Results of the PMR analysis: stratified by age and job type: (1) journeymen

Cause	Age (years)							
	20-64 (n = 189)				≥65 (n = 142)			
	Obs	Exp	O/E	Poisson 1 sided p*	Obs	Exp	O/E	Poisson 1 sided p*
All cancer,	23	29.12	0.79	0.15	25	25.04	1.0	0.55
Ca buccal, lip, pharynx	2	1.26	1.59	0.36	0	0.7	—	—
Ca larynx	0	0.69	—	—	0	0.4	—	—
Ca trachea, bronchus, lung	10	8.77	1.14	0.38	12	6.19	1.94	0.025
Ca oesophagus	0	0.96	—	—	0	0.77	—	—
Ca stomach	1	2.87	0.35	0.22	1	3.16	0.32	0.18
Ca intestines, rectum	1	2.3	0.44	0.33	1	2.44	0.41	0.30
Ca prostate	1	0.86	1.17	0.58	4	3.88	1.03	0.54
All non-malignant respiratory	22	13.22	1.66	0.02	26	19.28	1.35	0.08
Respiratory tuberculosis	2	1.0	2.01	0.26	1	0.46	2.17	0.37
All circulatory	78	90.52	0.86	0.10	71	76.28	0.93	0.30
All poisonings, accidents	39	11.52	3.38	0.000	3	6.16	0.49	0.14

*In the direction of the observed value.

Table 3 Results of the PMR analysis: stratified by age and job type: (2) production moulders

Cause	Age (years)							
	20-64 (n = 74)				≥65 (n = 14)			
	Obs	Exp	O/E	Poisson 1 sided p*	Obs	Exp	O/E	Poisson 1 sided p*
All cancer,	7	8.92	0.78	0.33	4	2.44	1.64	0.23
Ca buccal, lip, pharynx	0	0.35	—	—	0	0.7	—	—
Ca larynx	0	0.19	—	—	0	0.04	—	—
Ca trachea, bronchus, lung	2	2.31	0.87	0.59	1	0.62	1.62	0.46
Ca oesophagus	3	0.28	10.87	0.03	0	0.08	—	—
Ca stomach	1	0.78	1.28	0.54	2	0.3	6.67	0.04
Ca intestines, rectum	0	0.73	—	—	0	0.23	—	—
Ca prostate	0	0.2	—	—	0	0.38	—	—
All non-malignant respiratory	7	3.97	1.76	0.11	1	1.97	0.51	0.41
Respiratory tuberculosis	0	0.33	—	—	0	0.04	—	—
All circulatory	30	28.9	1.04	0.44	5	7.65	0.65	0.23
All poisonings, accidents	19	3.2	5.94	0.000	1	0.71	1.41	0.51

*In the direction of the observed value.

production moulders (O/E = 1.04) showed reduced PMRs, all of which were non-significant (p values ranging from 0.1-0.44).

RPMR, MOR, and PCMR analysis

Table 4 shows the results of the case-control studies comparing the odds ratio when using three different control groups (see methods) and the ratio PMR (journeymen):PMR (production moulders) for malignant and non-malignant respiratory disease. In all instances the odds ratio is raised for both malignant and non-malignant respiratory causes of death regardless of the definition of controls. Owing to low cell sizes none of the results reached statistical significance.

Discussion

ACCURACY OF DEATH CERTIFICATES

Death certificate information for South African whites is reasonably accurate and complete. In a study among gold miners information derived from a necropsy compared favourably with the cause of death on death

certificates. There was 92% agreement for ischaemic heart disease, 83% for lung cancer, 72% for non-malignant respiratory disease, and 78% for accidental causes.¹⁸

COMPLETENESS OF THE COHORT

Those iron moulders who left the union and subsequently died out of benefit were not followed up. Current publications suggest that a proportion of these may have left due to health reasons because of the particularly arduous nature of this industry.¹⁹ Subsequently, the data available for analysis may represent a healthier subset of the full cohort. A bias may also be present regarding job and disease ascertainment. Overall PMRs stratified by age and job type are higher than those stratified by age alone. The direction of this bias is not fully understood but may be related to the completeness of information related to causes of deaths assumed to be associated with a particular job type.

PMR STUDY

The increased PMR for lung cancer and respiratory

Table 4 Odds ratios (and two tailed probability values) using different control groups

Age stratification	PMR _{JM} :PMR _{PM} (RPMR)	Lung cancer		
		All other causes (MOR i)*	All other causes excluding respiratory diseases (MOR ii)*	All other cancers (PCMR)
20-64	1.31 (0.19)	2.01 (0.19)	2.07 (0.19)	1.92 (0.28)
≥65	1.20 (0.39)	1.20 (0.39)	1.38 (0.38)	2.76 (0.52)
Age stratification	PMR _{JM} :PMR _{PM} (RPMR)	Respiratory disease		
		All other causes (MOR i)*	All other causes excluding lung cancer (MOR ii)*	All other cancers excluding lung cancer (PCMR)
20-64	0.94 (0.77)†	1.26 (0.78)†	1.3 (0.13)†	1.21 (0.26)
≥65	2.65 (0.31)	2.91 (0.20)	3.0 (0.19)	2.0 (0.46)

*See methods section.

†These used the chi-squared test (1 df) with continuity correction. In all others Fishers exact test, two tailed probabilities were used.

disease in the older iron moulders is consistent with most other studies concerned with occupational exposure to foundry environments.^{11 12 20-25} In one particular PMR study among foundrymen the overall lung cancer PMR was 1.44 and the overall PMR for respiratory disease was 1.38.¹² The lowered PMR for circulatory disease is also consistent with other studies suggesting that strong selective effects operate in this industry. A striking difference between this and other studies is the high PMRs for injuries and poisonings in the younger iron moulders—that is, those who died before age 65. In the PMR study referred to above the PMR for accidents was 78.

RPMR, MOR, AND PCMR ANALYSIS

Control groups are usually chosen depending on the aims of a particular study and the state of the art knowledge about the effect of a particular exposure on other causes of death. The use of different referent populations had a small but variable effect on the odds ratio for lung cancer and for respiratory disease. At the same time there is an increase in random variation, with none of the comparisons reaching statistical significance. In all except one instance the MOR and PCMR odds ratios exceeded the RPMR odds ratio.

SMOKING AS A CONFOUNDER

Smoking cannot fully explain the increased PMRs for several reasons: there are no increases in PMRs in other related causes of death such as circulatory disease; a considerably larger proportion of smokers must be present in a cohort to make a significant contribution to the odds ratio and, finally, SMRs (in this case the approximation could hold for PMRs) exceeding 150 cannot be explained by increases in smoking alone.^{26 27}

Conclusion

This study has shown that certain age classes of iron moulders are at increased risk of respiratory disease and lung cancer when compared with the general population. This finding is consistent with world publications on the effects of occupational exposure to foundry environments and inconsistent with the hypothesis that the excess PMRs are due to excess smoking in this cohort. The increased risk of respiratory disease and lung cancer among journeymen when compared with production moulders is poorly understood, and could be artifactual owing to the relatively small differences in the odds ratio and the low statistical significance between the two job types.

A high PMR for injuries and poisonings is consistent with the iron and steel industry's high accident fatality rate.²⁸ This warrants further investigation as the ICD codes in this study did not distinguish

between industrial and non-industrial accidents.

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Destruction of manuscripts

From 1 July 1985 articles submitted for publication will not be returned. Authors whose papers are rejected will be advised of the decision and the manuscripts will be kept under security for three months to deal with any inquiries and then destroyed.