ELECTRONIC PAPER

Mortality and cancer incidence in a cohort of meatworkers

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Aims: To determine the risk of all cause mortality, cause specific mortality, and incident cancer in meatworkers.

Methods: In a retrospective cohort study, a list of members of a meatworkers union in Australia was matched with the national death and cancer registries. Standardised mortality ratios (SMR) and standardised incidence ratios (SIR) were calculated using Australian population rates. Exposure to animal viruses, animal blood, animal faeces, and plastic pyrolysis products was assigned according to job title. A nested case control analysis examined the risk of mortality and cancer incidence by each exposure.

Results: There were approximately 20 000 subjects available for analysis. Male workers had increased risk of mortality from all causes (SMR 116, 95% CI 105 to 128) and from injury (SMR 131, 95% CI 108 to 157). Risk of incident lung cancer in males was non-significantly increased (SIR 164, 95% CI 97 to 259) and males had a raised risk of head and neck cancer (SIR 188, 95% CI 103 to 315). There were no significant associations with specific exposures.

Conclusions: Compared to the general Australian population, meatworkers have increased risk of death from all causes, death from injury, and incident lung and head and neck cancer. Analysis by occupational exposures did not disclose any strong evidence of specific occupational risk factors, although this analysis was limited by small numbers of some outcomes and exposure assessment which was based on job titles only.

Work in abattoirs is anecdotally thought to be a dangerous occupation with high risk of musculoskeletal disorders, infectious diseases, skin infections, and cuts.[1] A few studies have examined the overall mortality of meatworkers, showing increased risk of all cause mortality as well as death from cancer, circulatory disease, and injury,[2] and small increases in overall mortality or cancer mortality in various subgroups of meatworkers.[3] However, a British study found no increase in any of the broad causes of death in meatworkers.[4]

There is evidence that employment as a meatworker is associated with an increased risk of several forms of cancer. There is some reasonably consistent evidence of increased risks of lung cancer in butchers and abattoir workers.[2–11] Some authors have speculated that this is due to either cigarette smoking or from the fumes which are produced when plastic wrapping is heat sealed.[5 6 12] The evidence for increased risks of lymphohaematopoietic (LH) cancers is not so consistent.[2 5 13–20] The risks of other cancers and other causes of death are inconsistent and often based on small numbers.

This study aimed to describe the causes of death among meatworkers in Australia and to determine whether the risk of death from any cause was increased compared to the Australian population. We also wished to determine whether the risk of incident cancers (particularly lung and LH cancers) was increased in those meatworkers potentially exposed to animal viruses and exposed to animal blood, and those meatworkers exposed to plastic pyrolysis products.

METHODS

The cohort consisted of all financial members of the Queensland Branch of the Australasian Meat Industry Employees Union (AMIEU) in Australia. The union represents workers employed in poultry processing, abattoirs, boning rooms, retail and supermarket meat rooms, cold storage, and smallgoods manufacturing. The industry is highly unionised and it is thought that most meatworkers in the states of Queensland, northern New South Wales, and the Northern Territory are members of this branch of the union.

The AMIEU membership records were computerised in 1984. The information held by the union included: last name, first name or initial, sex, date of birth, date joined union, date left union, Australian state (Queensland, New South Wales, or Northern Territory), company, and job title. Not all information was available on all subjects. For all members recorded on the database this information was extracted from the union records and matched with the National Death Index (NDI) and the National Cancer Statistics Clearing House (NCSCH). The NDI contains records of all deaths registered in Australia between 1982 and 1999. Age at death was available on almost all NDI records; date of birth was available for Queensland since 1996, for New South Wales since 1992, and for the Northern Territory since 1991.

The NCSCH contains records of all cancers registered in all states except South Australia. Cancer registration has been mandatory in all states of Australia since 1982 and the data are considered to be virtually complete. Measures of data quality are only published from the New South Wales Registry; these show that about 90% of cancers are histologically verified and only 1–2% are reported by death certificate only.[21] These values are better than those from population based registries in other countries. Data were available until 1997 in all states except New South Wales, which was

Abbreviations: BLV, bovine leukaemia virus; CI, confidence interval; CVD, cardiovascular disease; HPV, human papillomavirus; LH, lymphohaematopoeitic; NCSCH, National Cancer Statistics Clearing House; NDI, National Death Index; OR, odds ratio; SIR, standardised incidence ratio; SMR, standardised mortality ratio

Main messages

- Meatworking is a dangerous occupation, with increased risk of death from all causes compared to the general population.
- Deaths from injury are higher in meatworkers, particularly deaths from motor vehicle accidents.
- All cause cancer rates are similar to those in the general population.
- Increases in risk may be due to selection of a population which tends to undertake more risky behaviours (for example, smoking, drinking), as specific associations with occupational exposures were not found in this study.

Policy implications

- General promotion of healthy behaviours may be of use in decreasing the risk of mortality in meatworkers.

complete up until 1996. Date of birth was available on the majority of records in the NCSCH.

Data matching was undertaken using a probabilistic record linkage package called Automatch. Matching relies primarily on name or phonetic versions of the name and on date of birth and sex.

Because of privacy concerns, the decisions on which matches were accepted were made by staff at the NDI and NCSCH. They manually reviewed possible matches to determine which ones were most likely to be correct. The file with names removed was then forwarded to the authors.

This study was approved by the Monash University Standing Committee on Ethics in Research involving Humans and the Ethics Committee of the Australian Institute of Health and Welfare.

The exposure assessment used information on job title and employer. For each union member we had a three letter code denoting their job title and a number relating to the employer. There were 82 job codes, with the most common ones being labourer, packer, process worker, retail butcher, boner, slicer, slaughterman, and knife hand. Members of the union staff examined the list of employers and categorised each work site as to whether it was a red meat or poultry abattoir, a small goods manufacturer, or a retail butcher. A list was then made of all combinations of job title and type of work present in the cohort (for example, boner in red meat abattoir; labourer in smallgoods manufacturer). These combinations were reviewed by a public health veterinarian (SF) with over 15 years of experience in the meat industry. He classified each job qualitatively according to the potential level of exposure to animal viruses, animal blood, animal faeces, and plastic pyrolysis products. Exposure to animal blood and plastic pyrolysis products in the meat industry was classified as follows: low for those jobs with exposure at about the level found as background exposure in the industry; high for those jobs with the highest potential exposure within the industry; and medium for those jobs with potential exposure between the other two groups. No account was taken of the time when the job was done.

Duration of exposure was calculated as the time between joining the union and leaving the union. Those still in the union at the end of the year 1999 for deaths and 1997 for cancers were censored at that time.

The sex of approximately half the cohort was unrecorded, but sex could easily be allocated to all except 1888 subjects using their first or second names. Of these remaining 1888 subjects, all were classified as male except for those whose job titles tended to be held by females in the cohort (casual, retail, packer, and process worker). Only 928 of these subjects also had date of birth available, so were included in the cohort.

For subjects whose date of joining was missing (n = 31), the date of joining was considered to be the date they turned 15 years old. Members on the list were excluded from analysis if they: were missing a date of birth (n = 11 670); had obvious errors in date of birth or date joined the union such that they were aged less than 10 years old when they joined the union (n = 24); joined the union after 1999 (n = 157); or were missing information on job title (n = 44).

In the external analyses we compared the mortality and cancer incidence experience of the cohort with the Australian population rates using indirect standardisation. Standardised ratios were calculated for each sex using rates specific for calendar year and five year age group (up to age 80 years). Standardised mortality ratios (SMRs) were calculated for all cause mortality; mortality from cancer (ICD-9 codes 140–239), circulatory disease (390–459), respiratory disease (460–519), and injury (800–999). These are the four major causes of death in Australia. In the calculation of exact person years, for estimating expected deaths, we assumed that all subjects lost to follow up were still alive on 31 December 1999 or were censored at age 80 years, whichever was earlier.

Standardised incidence ratios (SIRs) were calculated for total cancer incidence; and for incidence of sites with more than 10 cases: the head and neck (140–149, 160–161), colorectum (153–154), lung (162), melanoma (172), breast (174–175), prostate (185), urinary system (188–189), genitalia (180–183), and LH system (200–208). In the calculation of exact person years, for estimating expected cancers, we assumed that all subjects lost to follow up were still alive on 31 December 1996 or were censored at age 80 years, whichever was earlier.

For the internal analyses we calculated effect measures with outcomes as above and adjusting for age and sex. The exposure variables used were: animal viruses, animal blood, animal faeces, plastic pyrolysis products, type of industry (red meat abattoir, poultry processing, retail, and smallgoods). Analyses were undertaken for all cause mortality, mortality from cancer, circulatory disease, respiratory disease, and injury; total cancer incidence; and incidence of the four most common cancers (colorectum, lung, melanoma, LH). A nested case/control method was used to calculate risk ratios,[22 23] where cases of cancer were matched to all subjects from the cohort who had not developed cancer of this site by the year of death of the case and were the same age and sex. At least five controls were selected. All the analysis was done using Stata 7 statistical software.[24]

RESULTS

There were 31 124 subjects in the union database. Of these, 19 229 (52.2%) had adequate information and were included in the mortality study, and 17 135 (46.5%) were included in the cancer incidence study (excluding those who joined the union after 1996). Those included in the study were more likely to be male, to live in Queensland, and to work in red meat abattoirs, but had similar exposures to those who were not included in the study (table 1).

Subjects included in the study had a mean age at joining of 26.7 years (range 11–70 years), and a mean age on leaving the union of 31.25 years (range 13–74 years). Length of time spent as a union member ranged from less than 1 year to 54 years.

Compared to the general Australian population, all cause mortality was increased by nearly 20% for both male and female meatworkers (table 2). The increase was statistically significant in males. Males also had a statistically significant increase in injury mortality. In females, the numbers of deaths were much lower and the confidence intervals correspondingly wider than in males. Mortality from cardiovascular disease and respiratory disease in females were increased but the increases were not statistically significant.

Table 1 Comparison of characteristics of union members included with those excluded from the study

Characteristic	Person years in mortality study	Included in study		Excluded from study
		Mortality (n=19229)	Incidence (n=17135)	(n=11895)
Male sex	106465.1	71.2	71.4	63.2
Resident in Queensland	144347.1	98.9	98.8	95.7
Type of plant				
Poultry	15943.3	10.4	11.0	17.7
Red meat	117398.3	78.0	77.0	69.0
Retail	6586.5	7.1	7.2	9.4
Smallgoods	6430.8	4.5	4.8	3.4
Unknown	–	0	0	0.4
Animal virus exposure				
Low	70548.8	56.7	54.9	56.6
Medium	44491.0	26.7	27.8	26.7
High	31319.1	16.6	17.3	16.7
Animal blood exposure				
Low	66212.4	51.0	49.1	51.0
Medium	63908.4	40.1	42.4	40.9
High	16238.2	8.1	8.5	8.1
Animal faeces exposure				
Low	115326.5	80.7	79.9	80.1
Medium	23132.9	11.6	12.2	11.7
High	2309.5	1.3	1.4	1.3
Unknown	5590.1	6.4	6.5	6.4
Plastic product exposure				
Low	120935.2	80.0	80.4	80.0
Medium	25423.9	20.0	19.6	20.0

Table 2 Standardised mortality ratios and standardised incidence ratios for meatworkers*

Mortality cause or cancer type	Males no. outcomes	Males	Females no. outcomes	Females
All cause SMR	395	116 (105 to 128)	63	117 (90 to 150)
Cancer SMR	92	98 (79 to 121)	22	90 (57 to 137)
Cardiovascular SMR	81	90 (72 to 112)	10	113 (54 to 209)
Respiratory SMR	12	80 (41 to 139)	4	152 (41 to 389)
Injury SMR	117	131 (108 to 157)	8	85 (37 to 167)
All cancers SIR	176	94 (80 to 108)	40	59 (42 to 80)
Head and neck cancers SIR	14	188 (103 to 315)	3	339 (68 to 991)
Colorectal cancers SIR	28	115 (76 to 166)	3	55 (11 to 162)
Lung cancer SIR	18	164 (97 to 259)	1	40 (0.5 to 224)
Melanoma SIR	34	110 (76 to 154)	11	96 (48 to 172)
Breast cancers SIR			7	30 (12 to 61)
Prostate cancers SIR	13	59 (31 to 101)		
Urinary cancers SIR	12	98 (51 to 171)	2	130 (15 to 470)
Genital cancers SIR	6	70 (25 to 151)	5	53 (17 to 125)
LH neoplasms SIR	20	103 (63 to 159)	4	89 (24 to 227)

*Compared to Australian population mortality and cancer incidence rates.

Standardised incidence ratios for cancer were significantly increased for head and neck cancers in male workers but for no other cancers (table 2). Lung cancer in male meatworkers was more common than in the general population with the lower bound of the confidence interval just below 1. In females, the SIR for all cancers was significantly decreased, due primarily to a significantly lower risk of breast cancer. The SIR for head and neck cancers in females was increased, but this was based on only three cases.

High exposure to viruses was allocated to jobs such as boner and slaughterman; slaughtermen and abattoir butchers had high exposure to animal blood; high exposure to plastic pyrolysis products was not allocated to any workers, and medium level exposure was allocated to packers and retail butchers; and workers in casings, offal, and hides had high exposure to animal faeces.

Analysis by exposure group showed very little association between specific occupational exposures and mortality (table 3). Compared to those working in red meat abattoirs, retail butchers had a significantly increased risk of death from cardiovascular disease with very wide confidence intervals. There was a significant decrease in risk of death with increased time in the union and with increased time exposed to blood products.

The only significant result for exposure and cancer incidence was a protective effect for lung cancer in those exposed at a medium level to animal blood (table 4). There was no dose response finding and it is likely this is a chance effect. Odds ratios for many exposures were non-significantly protective. Regarding the specific hypotheses for this study, there was a doubling of risk for LH cancers in those exposed to high levels of animal blood (OR 2.16, 95% CI 0.5 to 9.0) and a slight increase in lung cancer in those exposed to plastic pyrolysis products (OR 1.46, 95% CI 0.2 to 10.5). A tripling of risk of colorectal cancer in those exposed to plastic pyrolysis products (OR 3.0, 95% CI 0.4 to 22.8) was not statistically significant. Small numbers in the different types of abattoir meant many ORs could not be calculated for the analyses by

Table 3 Odds ratios* for mortality by exposure for meatworkers

Exposure	All cause mortality (n=458)	Cancer (n=114)	Cardiovascular disease (n=91)	Respiratory disease (n=16)	Injury (n=125)
Animal blood					
Low	1.0	1.0	1.0	1.0	1.0
Medium	0.89 (0.71 to 1.11)	0.70 (0.42 to 1.16)	0.98 (0.54 to 1.75)	1.72 (0.52 to 5.72)	0.95 (0.62 to 1.44)
High	0.83 (0.59 to 1.16)	0.70 (0.34 to 1.46)	1.36 (0.60 to 3.10)	1.49 (0.30 to 7.29)	0.87 (0.46 to 1.64)
Animal viruses					
Low	1.0	1.0	1.0	1.0	1.0
Medium	0.80 (0.62 to 1.02)	0.69 (0.40 to 1.19)	0.67 (0.35 to 1.27)	0.99 (0.21 to 4.59)	0.91 (0.57 to 1.45)
High	0.90 (0.68 to 1.18)	0.73 (0.39 to 1.37)	0.79 (0.40 to 1.56)	2.01 (0.94 to 8.16)	1.03 (0.62 to 1.69)
Animal faeces					
Low	1.0	1.0	1.0	1.0	1.0
Medium	0.80 (0.61 to 1.06)	0.78 (0.44 to 1.40)	0.86 (0.44 to 1.70)	0.59 (0.15 to 2.33)	0.76 (0.45 to 1.31)
High	0.94 (0.45 to 1.99)	0.75 (0.18 to 3.12)	0	0	2.30 (0.87 to 6.09)
Plastic pyrolysis					
Low	1.0	1.0	1.0	1.0	1.0
Medium	0.97 (0.65 to 1.43)	1.09 (0.49 to 2.42)	0.51 (0.14 to 1.86)	0.45 (0.06 to 3.15)	1.18 (0.59 to 2.38)
Type of work					
Red meat abattoir	1.0	1.0	1.0	1.0	1.0
Poultry abattoir	1.48 (0.99 to 2.23)	1.69 (0.66 to 4.32)	0.99 (0.25 to 3.93)	–	1.57 (0.81 to 3.07)
Retail butcher	1.19 (0.64 to 2.23)	0.88 (0.11 to 7.29)	5.59 (1.06 to 29.4)	0.77 (0.05 to 11.6)	0.40 (0.10 to 1.70)
Small goods	1.03 (0.52 to 2.05)	0.89 (0.21 to 3.78)	0.40 (0.04 to 4.11)	–	1.29 (0.41 to 4.02)
Duration					
<2 years	1.0	1.0	1.0	1.0	1.0
2+ years	0.39 (0.30 to 0.52)	0.51 (0.27 to 1.00)	0.51 (0.23 to 1.15)	0.97 (0.11 to 8.87)	0.43 (0.27 to 0.67)
Blood contact					
<2 years	1.0	1.0	1.0	1.0	1.0
2+ years	0.55 (0.43 to 0.69)	0.58 (0.35 to 0.96)	0.76 (0.43 to 1.35)	1.19 (0.36 to 3.98)	0.60 (0.38 to 0.93)

*Adjusting for age and matched for sex.
–, no cases.

Table 4 Odds ratios* for cancer incidence by exposure for meatworkers

Exposure	All cancers (n=220)	Colorectal cancer (n=31)	Lung cancer (n=19)	Melanoma (n=46)	LH cancers (n=24)
Animal blood					
Low	1.0	1.0	1.0	1.0	1.0
Medium	0.75 (0.53 to 1.00)	0.74 (0.26 to 2.15)	0.12 (0.02 to 0.60)	0.68 (0.35 to 1.34)	0.54 (0.20 to 1.48)
High	0.65 (0.38 to 1.09)	1.59 (0.45 to 5.66)	0.24 (0.02 to 2.57)	0.47 (0.15 to 1.48)	2.16 (0.52 to 8.98)
Animal viruses					
Low	1.0	1.0	1.0	1.0	1.0
Medium	0.71 (0.49 to 1.04)	0.67 (0.21 to 2.22)	0.22 (0.05 to 1.11)	0.48 (0.22 to 1.03)	0.50 (0.17 to 1.48)
High	0.70 (0.45 to 1.08)	1.88 (0.57 to 6.17)	0.32 (0.05 to 1.87)	0.69 (0.30 to 1.61)	0.95 (0.27 to 3.27)
Animal faeces					
Low	1.0	1.0	1.0	1.0	1.0
Medium	0.70 (0.46 to 1.08)	1.24 (0.46 to 3.32)	0.63 (0.13 to 3.10)	0.47 (0.19 to 1.17)	1.71 (0.57 to 5.08)
High	1.65 (0.54 to 5.08)	–	–	–	–
Plastic pyrolysis					
Low	1.0	1.0	1.0	1.0	1.0
Medium	1.40 (0.84 to 2.35)	3.0 (0.39 to 22.8)	1.46 (0.20 to 10.5)	1.28 (0.49 to 3.39)	0.77 (0.12 to 4.79)
Type of work					
Red meat abattoir	1.0	1.0	1.0	1.0	1.0
Poultry abattoir	1.09 (0.57 to 2.09)	0.99 (0.07 to 13.8)	–	0.71 (0.16 to 3.07)	–
Smallgoods	1.11 (0.45 to 2.76)	–	–	0.59 (0.10 to 3.52)	–
Retail butcher	0.58 (0.19 to 1.79)	2.69 (0.10 to 70.8)	1.30 (0.04 to 43.9)	–	–
Duration					
<2 years	1.0	1.0		1.0	1.0
2+ years	0.58 (0.36 to 0.92)	0.63 (0.11 to 3.48)	–	0.52 (0.20 to 1.32)	0.38 (0.09 to 1.61)
Blood contact					
<2 years	1.0	1.0	1.0	1.0	1.0
2+ years	0.65 (0.46 to 0.93)	1.96 (0.55 to 6.99)	0.58 (0.14 to 2.43)	0.32 (0.14 to 0.75)	0.71 (0.27 to 1.85)

*Adjusting for age and matched for sex.
–, no cases.

type of work. Meatworkers with longer duration in the union were at lower risk of cancer than short duration workers.

DISCUSSION

This cohort study of members of a large union of meatworkers has found that male meatworkers have increased risks of all cause mortality and injury mortality. Incidence of cancers of the head and neck and lung were increased, although the latter was not statistically significant. When different measures of exposure were examined, there was little association between occupational exposures and mortality or cancer incidence.

The AMIEU computerised all their membership records in 1984. They mark subjects as "active" or "inactive" depending on whether they are currently working in the meat industry, but they do not delete subjects from the database. The industry is highly unionised, and covered by only one union; it is thought that most meatworkers in the north eastern states are

members of the union. Thus we consider this a virtually complete listing of the workers in this industry. We had to exclude subjects who did not have a date of birth on the records. The subjects included in the study were more likely to be male, to reside in Queensland, and to work in the red meat industry. However, they did not differ from the excluded subjects in the prevalence of exposures. Selection bias was therefore minimal.

In this study we were unable to confirm live status, nor could we determine whether union members left the country after leaving the union. In addition, we had to rely on staff from the national registries to determine whether to accept possible matches. The matching process with the NDI is thought to be reasonably accurate. Two studies[25 26] have shown sensitivity to known deaths to be 89% and 95% respectively, and specificity for known live subjects to be 98% and 99%. However, one of these studies[26] was a cohort of elderly women, all of whom were Australian citizens; the other[25] was of members of a private health insurance company. Our cohort of meatworkers would have been of lower socioeconomic class and would contain more migrants than either of the other cohorts. We may therefore have missed deaths which occurred overseas, or matches may not have been made for names which had been Anglicised either on the union records or the death certificate.

On the other hand, because of the anonymous nature of the match, and the lack of date of birth on a large proportion of the NDI records, we may have included deaths which were not, in reality, matches. Exact matches (with exact date of birth and full name) were made for 46% of the deaths, with the remainder being exact match on full name and match on year of birth. The most conservative interpretation of these data would assume only 46% of matches were correct. We may therefore have overestimated the SMRs by a factor of two. This extreme level of error is unlikely.

The NCSCH has full date of birth on all subjects, so the matches with incident cancers may be considered more accurate. Of the total 116 deaths apparently from cancer, there were 51 deaths which did not match with the cancer registry. Of these, 19 were between 1995 and 1999 and may not have been registered by the cancer registries (which are always some years behind the death registration system). This suggests that up to 32 (27%) of the total 116 deaths from cancer may not have been correct matches. If these results are generalisable to all causes of death, we may have overestimated the SMRs by a factor of 30%.

Overall, we think the maximum amount of overestimation is likely to be 30%, and when combined with possible underestimation due to overseas deaths and misspellings of names, the error is likely to be less than that. If adjustment was made for this, we would still have an increased risk of all major causes of death in this cohort compared with the general Australian population. The lack of any healthy worker effect suggests that this group does have increased risk of mortality. This could be due to a lower socioeconomic status, or to increased risky behaviours such as smoking and alcohol use. In a random survey of Swedish men, butchers and slaughterhouse workers were found to have much higher prevalences of smoking than the entire sample (cited in Boffetta and colleagues[6]), although a study of Danish butchers found the prevalence of smoking to be very similar to that of other unskilled workers.[10] Another Swedish study found butchers to have nearly twice the risk of admission to hospital with alcoholism than other employed men.[27]

Assumptions of gender were made for 1888 subjects, of whom 928 had date of birth and were included in the analyses. Only eight deaths and six cancers were seen in these subjects.

The risk of lung cancer was increased by about 60% in male meatworkers in our cohort. Similar modest increases in the risk of lung cancer in meatworkers have been reported fairly consistently in various studies.[2–11] Only two of these studies were able to adjust for smoking status. One of these studies was a small case-control study with only 60 cases and 60 controls[28] nested within a cohort of members of a US meatworkers union. The crude odds ratio in this study for having ever worked in the meat industry was 3.5 (95% CI 1.1 to 11.0). Although smoking was very strongly associated with risk of lung cancer, adjusting for age, sex, and smoking did not alter this finding, which suggests smoking was not a confounder in this study. A strong relation with timing of the exposure was found, with adjusted ORs for <5 years, 5–10 years, and >10 years before diagnosis increasing from 1.6 to 2.7 to 5.5. A nested case-control study was also carried out in a Swedish cohort of butchers and meatworkers; it found small non-significant increases in risk of lung cancer in meatworkers involved in live animal care and meat curing after adjustment for smoking.[12] Increased risk of head and neck cancer in our cohort may also have been associated with cigarette smoking. Axelson[29] provided formulas to attribute the burden of lung cancer due to occupational exposures. Using his method, we assumed 60% of meatworkers are smokers, the relative risk of lung cancer is 10, and the rate of lung cancer in non-smokers is 12.6 per 100 000. The results suggested that an excess of about 36% of lung cancers in our cohort could be attributed to occupation. However, the rate of lung cancer in our meatworkers cohort was 110/100 000, which is much higher than the rates used in the Axelson paper.

A possible risk factor for lung cancer is exposure to fumes emitted when plastic is heated and sealed during meat wrapping. In our study those workers who were potentially exposed to plastic pyrolysis products had a slightly increased risk of lung cancer, but the confidence limits were extremely wide (OR 1.46, 95% CI 0.2 to 10.5). In the US study described above,[28] workers in supermarkets were 2.4 times more likely to develop lung cancer; however, again the confidence limits were very wide (0.3 to 19.2). In the Swedish study,[12] packaging workers were not at increased risk of lung cancer (RR 0.85, 95% CI 0.39 to 1.88).

We did not find an increase in risk of LH cancer in this cohort. An association between potential exposure to zoonotic viruses and LH cancer was one of the hypotheses of this study. Although the risk of LH cancer was increased in those with high exposure to animal blood, the confidence interval for this estimate was very wide (OR 2.16, 95% CI 0.5 to 9.0). The evidence for increased risks of LH cancers among meatworkers is not consistent. In a series of studies based on the same cohort of members of a meatworkers union, Johnson found slightly increased risks of LH cancer associated with poultry processing,[15] and various meatworking tasks.[5 18] A cohort study of Swiss butchers found an SMR of 122 (95% CI 63 to 212) based on nine cases.[2]

Other studies have examined the various types of LH cancers separately. A recent case-control study from New Zealand[20] found a strong association between working in an abattoir and leukaemia, which was strongest in those who had over two years exposure (OR 4.9, 95% CI 1.5 to 15.6). In a North American study using registry records,[19] the occupational group of meat cutting and wrapping was associated with a non-statistical significant increase of leukaemia risk. Another US study found no increase in the overall leukaemia mortality rate in butchers, but a doubling of risk of acute lymphocytic leukaemia.[16] In case-control studies, meatworkers have been found to have significantly increased risks of Hodgkin's disease[14] and non-Hodgkin's lymphoma[13] in some, but not all studies.[17] We did not have sufficient cases in our study to analyse the different types of LH cancer separately.

A number of animal viruses endemic in Australia are oncogenic in their host species, including bovine leukaemia virus (BLV), papillomaviruses (associated with squamous cell carcinomas in cattle and sheep), and the poultry viruses causing Marek's disease (herpes virus induced), avian leucosis, and avian reticuloendotheliosis (both retroviral induced). Despite

this, and the potential exposure of abattoir workers to these viruses, little evidence is available to suggest links with human cancers.

Epidemiological and serological studies to assess the zoonotic potential of BLV have been performed in groups of agricultural workers; although they concluded that BLV can cross the species barrier under experimental conditions, there was no evidence to indicate that the virus can affect humans.[30 31] Cutaneous warts caused by the human papillomavirus HPV7 show a high prevalence in meat handlers, although the reasons for this are not clear. Period prevalence rates for workers who slaughtered cattle and pigs were significantly higher than those for other meat industry workers.[32] It has been suggested that some constituent of animal flesh predisposes to replication of HPV7 in keratinised epithelium.[33] To date, there is no evidence for the zoonotic transmission of papillomaviruses from sheep and cattle to humans. Although avian oncogenic viruses have been shown to transform human cells in vitro, and sera from poultry workers has been shown to be positive for the viruses, little information is available on their zoonotic potential.[15] A recent paper from France discussed whether Marek's disease virus posed a public health hazard to humans.[34] Using a nested PCR assay, 202 human sera from individuals exposed and unexposed to poultry were examined for a Marek's disease virus gene. Twenty per cent of the samples tested positive; however, the prevalence of Marek's disease virus DNA was not significantly different between the groups.

We found a non-significant small increase in mortality from cardiovascular disease (CVD) in women meatworkers which was based on only 10 cases. A cohort of Swiss butchers had a similar increase in risk of CVD mortality (SMR 120, 95% CI 106 to 135).[2] However, a British cohort showed no increase in CVD (SMR 86, 95% CI 68 to 106).[4] Poultry slaughtering and processing workers have been found to have a slight increase of CVD (SMR 1.2, CI 1.0 to 1.5), which was most marked in white females.[15] It is possible that meatworkers in our study tend to have diets which contain a high proportion of fat and red meat,[2] and also that they smoke more cigarettes. The increase in retail butchers' risk of mortality from respiratory disease, and small increase in risk of lung cancer, seems to suggest that Australian retail butchers may have increased smoking rates, as do Swedish meatworkers (cited in Boffetta and colleagues[6]).

Mortality from injury was increased in males in our cohort, mainly in poultry and smallgoods workers. Of the 125 injury deaths, 42 (32.6%) were due to motor vehicle accidents and 50 (38.8%) due to suicide. In Australian men in 1999, 21% of injury deaths were due to motor vehicle accidents and 34% were due to suicide.[35] Poultry workers in the US have also been shown to have increased risk of motor vehicle accidents (SMR 1.5, 95% CI 1.0 to 2.3).[15] Swiss butchers also had an increased risk of violent death (SMR 150, 95% CI 111 to 199) which was mostly due to motor vehicle accidents, and less to suicide.[2] However, the risk of injury death in British meatworkers was not increased.[4]

We found that workers with short duration in the union had increased risk of death and cancer incidence compared to longer duration workers. Other occupational cohorts have shown that short term employees tend to have higher mortality rates than longer term workers.[36] This finding is thought to be due to the higher prevalences of risk factors such as smoking and alcohol use in itinerant workers.[37]

In women, there was a discrepancy between the cancer mortality and incidence results, with female members of the union at about the same risk of dying of cancer to the general population but at a lower risk of incident cancer. There were 15 cancer deaths recorded in female cohort members which were not recorded on the cancer registry. Four of these were deaths recorded after 1996 which would not yet have appeared on the cancer registry. The other 11 may have been due to mismatching of the death match, which was less accurate than the cancer match because of lack of date of birth information on the death index.

The assessment of exposures in this study was based on job title and employer, and no individual job specific data were available. This meant that there was no discrimination between the different tasks performed within jobs. Some workers may therefore have been misclassified as exposed when they were not, or vice versa. For example, working with green offal (gastrointestinal tract) would imply a high exposure to animal faeces, whereas working with red offal (heart, liver, kidneys, etc) would have less exposure. These two areas are often separate in a slaughterhouse. Similarly, working on the slaughter floor may not actually be associated with close carcase contact (kill-floor supervisor, cleaners). Misclassification of exposure would result in a diminution of observable effect measures and may explain why few positive results were found for the internal analyses.

Misclassification of death due to inaccurate matching would presumably be a non-differential misclassification which would move the RRs closer to the null value.

Overall, compared to the general Australian population, male meatworkers have increased risk of death from all causes; death from injury, especially motor vehicle accidents; and risk of incident lung cancer and head and neck cancer. Analysis by occupational exposures did not disclose any strong evidence of risk factors, although this was limited by small numbers of some outcomes. In addition, exposure assessment was based on job titles only, which probably led to misclassification in some cases as titles were often vague and difficult to link to specific tasks or to close contact with animal tissues or fluids.

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