2. Studies of Cancer in Humans

2.1 Cohort studies (Tables 2.1 and 2.2)

Among municipal firefighters, five studies evaluated the incidence of cancer and 15 assessed mortality – some with multiple reports. None of these was adjusted for smoking, or other potential confounders.

Mastromatteo (1959) conducted a cohort mortality study of all firefighters employed with the city fire department in Toronto, Ontario, Canada during 1921–1953. The cohort consisted of 1039 active and retired firefighters. A total of 325 firefighters (31%) were lost to follow-up. The followed cohort accrued 25 918 person–years of observation; 271 deaths were recorded. Causes of death were determined by the examination of death certificates. Comparison was made to age-specific death rates for the Province of Ontario. Because most of the firefighters were urban dwellers, the author calculated death rates for the City of Toronto. There was no excess mortality from cancer at all sites combined (34 observed, 30 expected), and no site-specific analysis of cancer mortality.

Musk *et al.* (1978) conducted a cohort mortality study in 5655 firefighters with three or more years of service in Boston, USA, during 1915–1975. Firefighters were identified from employment records. The observed cause of death as stated on the death certificates of 2470 deceased firefighters was compared with expected numbers based on rates for the male population of Massachusetts. Cancer risks were only presented by organ system, and no statistically significant increases were seen.

Eliopulos *et al.* (1984) conducted a cohort mortality study of all males employed as full-time firefighters by the Western Australian Fire Brigade during 1939–1978. The cohort consisted of 990 male firefighters and follow-up was 98.3% complete through examination of death certificates. The cohort accrued a total of 16 876 person–years of follow-up; 116 deaths were recorded. Mortality from all causes was less than expected (standardized mortality ratio [SMR], 0.80; 95% confidence interval [CI]: 0.67–0.96). For those firefighters already employed at the study start date, mortality was a little higher (SMR, 0.84) than for those who started later (SMR, 0.74). There was no tendency for rates to rise with increasing duration of employment. SMR for all malignancies was 1.09 (95% CI: 0.74–1.56). Standardized proportional mortality ratios (SPMRs) were calculated for cancers, primarily by organ system, and no statistically significant excesses were seen.

Vena and Fiedler (1987) examined all full-time employees of the City of Buffalo, USA, who worked at least 5 years during 1950–1979. A total of 1867 Caucasian male firefighters employed for at least one year as a firefighter were studied.

Table 2.1 Overview of cohort studies of firefighters

Reference	Location	Outcome, Design	Study Period	Number of Workers	Exposure Surrogates Used
Mastromatteo (1959)	Toronto, Canada	Mortality (SMR)	1921–1953	1039	None
Musk *et al.* (1978)	Boston, USA	Mortality (SMR)	1915–1975	5655	None
Eliopulos *et al.*, (1984)	Australia	Mortality (SMR, SPMR)	1939–1978	990	None
Vena & Fiedler (1987)	Buffalo, USA	Mortality (SMR)	1950–1979	1867	Duration of employment
Heyer *et al.* (1990)	Portland, USA Seattle, USA	Incidence (SIR) Mortality (SMR)	1974–1989 1945–1980	2447 2289	Duration of firefighting Duration of employment
Beaumont *et al.* (1991)	San Francisco, USA	Mortality (SMR)	1940–1970	3066	Duration of employment
Grimes *et al.* (1991)	Honolulu, USA	Proportionate Mortality	1969–1988	205	None
Demers *et al.* (1992a; 1992b; 1994)	Seattle, Tacoma, USA	Mortality (SMR) 1992a Mortality (SMR) 1992b Incidence (SIR) 1994	1944–1979 1944–1979 1974–1989	4546 4528 2447	
Giles *et al.* (1993)	Western Australia	Incidence (SIR)	1980–1989	2865	None
Guidotti (1993)	Calgary, Edmonton, Canada	Mortality (SMR)	1927–1987	3328	Duration of firefighting
Aronson *et al.* (1994)	Toronto, Canada	Mortality (SMR)	1950–1989	5995	Duration of employment
Tornling *et al.* (1994)	Stockholm, Sweden	Mortality (SMR) Incidence (SIR)	1931–1983	1153	Duration of employment Number of runs
Deschamps *et al.* (1995)	Paris, France	Mortality (SMR)	1977–1991	830	None
Baris *et al.* (2001)	Philadelphia, USA	Mortality (SMR)	1925–1986	7789	Duration of employment Number of runs Company type engine, ladder

Table 2.1 Overview of cohort studies of firefighters

Reference	Location	Outcome, Design	Study Period	Number of Workers	Exposure Surrogates Used
Bates *et al.* (2001)	New Zealand	Mortality (SMR) Incidence (SIR)	1977–1995	4221	Duration of employment
Ma *et al.* (2005)	Florida, USA	Mortality (SMR) Incidence (SIR)	1972–1999 1981–1999	36 813	None
Ma *et al.* (2006)	Florida, USA	Mortality (SMR) Incidence (SIR)	1972–1999 1981–1999	222 4528	None

Adapted from LeMasters *et al.* (2006)

Vital status was determined for 99% of the cohort, resulting in 470 observed deaths. Significantly elevated SMRs were found for benign neoplasms (SMR, 417), cancer of the colon (SMR, 183), and cancer of the bladder (SMR, 286). Cause-specific mortality was presented by the number of years employed, calendar year of death, year of hire, and latency. Cancer mortality was significantly higher in the long-term firefighters, and risk of mortality from all malignant neoplasms tended to increase with increasing latency. Statistically significant excesses of colon and bladder cancer were observed among firefighters employed for 40 or more years.

Beaumont *et al.* (1991) calculated mortality rates for 3066 firefighters employed during 1940–1970 at the San Francisco Fire Department, USA. Vital status was ascertained through to 1982, and observed and expected rates were computed using United States death rates. About 3% of the population was lost to follow-up. Mortality was examined by duration of employment as a firefighter. The total number deceased (1186) was less than expected (risk ratio [RR] = 0.90), and there were fewer cancer deaths than expected (RR = 0.95). However, there were significant excess numbers of deaths from oesophageal cancer (12 observed, six expected). A statistically significant excess of biliary and related cancer was observed among firefighters employed for 30 or more years.

Grimes *et al.* (1991) conducted a proportionate mortality study involving all male firefighters with at least one year of service in the fire department of the City of Honolulu, USA. The observed percentage of firefighter deaths from each cause from 1969–1988 was compared statistically to the expected numbers of deaths for all males aged over 20 years in Hawaii's general population. The proportionate risk ratio (PRR) for all malignant neoplasms was 1.19 (95% CI: 0.96–1.49). Significant increases in risk of death were found for brain cancer (PRR, 3.78), prostate cancer (RR, 2.61), and cirrhosis of the liver (PRR, 2.3). [The Working Group noted that it does not appear as though PRRs were standardized by age and calendar period as is standard practice for this type of analysis.]

Heyer *et al.* (1990) examined the mortality among 2289 firefighters from Seattle, Washington, USA employed during 1945–1980. Subsequently, Demers *et al.* (1992a) examined the mortality of 4546 firefighters who were employed by the cities of Seattle and Tacoma (Washington, USA), and Portland (Oregon, USA) for at least one year during 1944–1979. Demers *et al.* (1992b) also examined the cancer incidence in 4528 firefighters from Seattle and Tacoma during 1944–1979. Mortality in these firefighters was compared to United States national mortality rates and to mortality rates of police officers from the same cities. Mortality was examined by the duration of employment as a firefighter (i.e., actually controlling fires) rather than as an inspector or a support person. This mortality was then compared to a reference group of police from the same cities. Complete follow-up was achieved for 98% of the firefighters. During 1945–1989 (the cohort was the same as Demers *et al.* [1992a] but the follow-up lasted until 1989), 1169 deaths occurred in the study population, and 1162 death certificates (99%) were collected. There was no excess risk of overall mortality from cancer. Excesses of brain tumours (SMR, 2.1; 95% CI: 1.2–3.3) and lymphatic and haematopoietic cancers (SMR, 1.3; 95% CI: 0.9–1.8) were found. Younger firefighters (< 40 years of age) showed an excess risk of cancer (SMR, 1.45; 95% CI: 0.8–2.39), primarily due to brain cancer (SMR, 3.75; 95% CI: 1.2–8.7). The risk of lymphatic and haematopoietic cancers was greatest for men with at least 30 years of exposed employment (SMR, 2.1; 95% CI: 1.1–3.6), especially for leukaemia (SMR, 2.6; 95% CI: 1.0–5.4).

Demers *et al.* (1994) further examined the incidence of cancer in a subcohort of 2447 male firefighters who were employed for at least one year during 1945–1979 in Seattle and Tacoma, who were still alive on January 1st 1974. Incident cancer cases were ascertained through the Cancer Surveillance System of the Fred Hutchinson Cancer Research Center, a population-based tumour registry. The follow-up period was from 1974 to 1989. Cancer incidence in firefighters was compared with local rates and with the incidence among 1878 policemen from the same cities. The overall risk of cancer among firefighters was found to be similar to that of both the police (SIR, 1.0; 95% CI: 0.8–1.3) and the general male population (SIR, 1.1; 95% CI: 0.9–1.2). No excesses were observed for the most common organ sites. An elevated risk of prostate cancer was observed relative to the general population (SIR, 1.4; 95% CI: 1.1–1.7), but was less elevated compared with rates in policemen (incidence density ratio [IDR], 1.1; 95% CI: 0.7–1.8), and was not related to duration of exposure. The risk of colon cancer, although only slightly elevated relative to that of the general population (SIR, 1.1; 95% CI: 0.7–1.6) and the police (IDR, 1.3; 95% CI: 0.6–3.0), appeared to increase with duration of employment.

Giles *et al.* (1993) conducted a cancer incidence study of 2855 male firefighters employed by the fire brigade in Melbourne, Australia, during 1917–1988. All were operational personnel, who would more than likely have been called to combat fires. The follow-up period was from 1980 to 1989, and was estimated to have been 95% complete. To determine cancer incidence during the follow-up period, fire brigade employment records were linked to the Victorian Cancer Registry. SIRs were calculated by the direct method using the population of the State of Victoria as the reference group. The cohort accrued a total of 20 853 person–years, and 50 firefighters developed cancer during the period of observation. The SIR for all cancer sites and all ages combined was 1.13 (95% CI: 0.84–1.48). For firefighters under the age of 65 years, the all-site SIR was 0.84 (95% CI: 0.56–1.20); for those above 65 years of age, the all-site SIR was 2.14 (95% CI: 1.32–2.37). The only site-specific cancer that was elevated in the age group of 65 and older was colorectal cancer, with an SIR of 3.65 (95% CI: 1.13–7.94). The SIR for all other cancers in the age group 65 and above after removing colorectal cancer remained elevated, with a residual SIR of 1.83 (95% CI: 1.03–3.02).

Guidotti (1993) examined the mortality by cause of death for two cohorts totaling 3328 firefighters active during 1927–1987 in Edmonton and Calgary, Alberta, Canada. Associations were examined by cohort (before and after the 1950s) and by years of service weighted by exposure opportunity. The study attained 96% follow-up of vital status and over 64 983 person–years of observation; 370 deaths were recorded. Excesses were observed for all malignant neoplasms (SMR, 1.3; 95% CI: 1.0–1.6), and for cancers of the lung (SMR, 1.4; 95% CI: 0.9–2.1), bladder (SMR, 3.2; 95% CI: 0.9–8.1), kidney and ureter (SMR, 4.1; 95% CI: 1.7–8.5), colon and rectum (SMR, 1.6; 95% CI: 0.9–2.7), pancreas (SMR, 1.6; 95% CI: 0.5–3.6), and leukaemia, lymphoma and myeloma (SMR, 1.3; 95% CI: 0.6–2.3). The lung cancer excess was confined to Edmonton; there was no consistent association with duration of employment, exposure opportunity, or decade of entry into the cohort (before or after the 1950s) except that the highest risk was observed among Edmonton firefighters with over 35 weighted years of service. Urinary tract cancer excess was observed mostly among firefighters entering service after 1950, and appeared to increase with the length of service and exposure opportunity, and was observed in both cities.

Aronson *et al.* (1994) conducted a retrospective cohort mortality study of all male employees of the six fire departments within metropolitan Toronto, Ontario, Canada (n = 5995). The study population consisted of all male firefighters who had worked for at least 6 full months in metropolitan Toronto at any time during 1950–1989. Mortality was ascertained through computerized record linkage and compared to that of the male Ontario population specific to cause, age, and calendar period during 1950–1989. The cohort accrued 114 008 person–years and the average duration of follow-up was 21 years. Mortality was examined by duration of exposure. The SMR for all malignant neoplasms was 105 (95% CI: 91–120), for brain tumours, 201 (95% CI: 110–337), and for “other” malignant neoplasms, 238 (95% CI: 145–367). Non-significant increases in risk were observed for some other sites, in particular rectum (SMR, 171), larynx (SMR, 140), and testis (SMR, 252).

Tornling *et al.* (1994) conducted a cohort mortality study of all male fire fighters employed for at least 1 year in the City of Stockholm, Sweden during 1931–1983 (n = 1116). The population was identified from annual employment records. Follow-up for mortality was from 1951 until 1986, and for cancer incidence from 1958 to 1986. Except for four persons who had emigrated from Sweden, follow-up was 100% complete. To assess the occupational exposure as a firefighter, an index of participation in number of fires was calculated for each individual based on the number of reports on all fires in Stockholm that had been maintained since the beginning of the twentieth century. The all-site cancer mortality in 1958–1986 was equal to the expected (SMR, 100; 95% CI: 83–119). An excess of stomach cancer incidence (SIR, 192; 95% CI: 114–304; 18 observed versus 9.37 expected) was observed. There was also a tendency for higher incidence and mortality in stomach and brain cancers with increasing number of fires. Four brain cancer cases were observed compared to 0.8 expected (SIR, 496; 95% CI: 135–1270) in the highest exposure category.

Table 2.2. Cohort studies of cancer among firefighters

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Buccal cavity							
Beaumont *et al.* (1991), California, USA	3066 male firefighters employed 1940–70 Buccal cavity and pharynx	Fire department records	Overall	11	1.4 (0.7–2.6)		
Baris *et al.* (2001), Pennsylvania, USA	7789 firefighters employed 1925–86 Buccal cavity and pharynx	Employee service records					
			Overall	19	1.4 (0.9–2.1)		
			Duration of employment		**SMR**		
			≤9 yrs	4	1.2 (0.4–3.1)		
			10–19 yrs	9	1.8 (0.95–3.5)		
			≥20 yrs	6	1.1 (0.5–2.4)		
			Hiring period				
			Hired before 1935	10	2.1 (1.1–3.9)		
			1935–44	4	0.9 (0.3–2.3)		
			After 1944	5	1.1 (0.5–2.6)		
			Number of runs				
			Low (<3323)	7	1.7 (0.8–3.6)		
			Medium (3323–5099)	0	0		
			High (5099+)	2	0.8 (0.2–3.1)		
Ma *et al.* (2005), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SMR**	Age, calendar year	
			Men	7	0.4 (0.2–0.9)		
			Women	0	–		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Ma *et al.* (2006), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SIR**	Age, calendar year	
			Men	39	0.7 (0.5–0.9)		
			Women	0	0		
Oral and pharyngeal cavity / UADT							
Demers *et al.* (1992a), Northwest, USA	4546 male firefighters employed 1944–79 in selected Northwest cities	Employment records			**SMR**		
			Overall	7	0.8 (0.3–1.7)		
Demers *et al.* (1992b), Northwest, USA	4528 firefighters and police officers employed by the cities of Seattle and Tacoma; oral and pharyngeal	Employment records			**SIR**		Data for firefighters and police combined
				19	1.2 (0.7–1.9)		
					SMR		
				4	1.0 (0.3–2.6)		
Giles *et al.* (1993), Australia	2865 male firefighters employed 1917–89 Upper aerodigestive	Employment and union records, payrolls			**SIR**		
			Overall	6	1.5 (0.5–3.2)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Guidotti (1993), Alberta, Canada	3328 firefighters employed 1927–87	Personnel files			**SMR**		
			Overall	2	1.1 (0.1–4.1)		
	Oral						
Aronson *et al.* (1994), Ontario, Canada	5373 male firefighters employed 1950–89	Employment records			**SMR**		
			Overall	4	1.4 (0.4–3.6)		
	Pharynx						
Demers *et al.* (1994), Northwest, USA	2447 male firefighters employed 1974–89	Employment records			**SIR**		
			Overall	11	1.1 (0.6–2.0)		
			<10 yrs	2	1.4 (0.2–5.1)		
			10–19 yrs	4	2.5 (0.7–6.4)		
			20–29 yrs	2	0.3 (0.0–1.2)		
			≥30 yrs	3	3.9 (0.8–11.0)		
Deschamps *et al.* (1995), France	830 male firefighters employed 1977–91	Employment records			**SMR**		
				2	0.8 (0.1–2.9)		
	Pharynx						

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Stomach							
Eliopulos *et al.* (1984), Australia	990 firefighters employed 1939–78	Western Australian Fire Brigade records	Overall	5	**SPMR** 2.0 (0.7–4.7)		
Vena & Fiedler (1987), New York State, USA	1867 male firefighters employed 1950–79	Death certificates	Overall	7	**SMR** 1.2 (0.5–2.5)		
Heyer *et al.* (1990), Washington, USA	2289 male firefighters employed at least 1 yr, 1945–80; follow-up until 1983	Employment records	Overall	6	**SMR** 1.1 (0.4–2.5)		
Beaumont *et al.* (1991), California, USA	3066 male firefighters employed 1940–70	Fire department records	Overall	22	**SMR** 1.3 (0.8–2.0)		
Grimes *et al.* (1991), Hawaii, USA	205 male firefighters	Death certificates	Overall	2	**PRR** 0.8 (0.3–2.1)		Not clear if standardized by age and calendar period

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Demers *et al.* (1992a), Northwest, USA	4546 male firefighters employed 1944–79 in selected Northwest cities	Employment records			**SMR**		
			Overall	16	1.1 (0.6–1.7)		
Guidotti (1993), Alberta, Canada	3328 firefighters employed 1927–87	Personnel files			**SMR**		
			Overall	6	0.8 (0.3–1.8)		
Aronson *et al.* (1994), Ontario, Canada	5973 male firefighters employed 1950–89	Employment records			**SMR**		
			Overall	7	0.5 (0.2–1.1)		
Demers *et al.* (1994), Northwest, USA	2447 male firefighters employed 1974–89	Employment records			**SIR**		
			Overall	8	1.4 (0.6–2.7)		
			<10 yrs	2	3.0 (0.4–11.0)		
			10–19 yrs	1	1.2 (0.0–6.9)		
			20–29 yrs	4	1.1 (0.3–2.9)		
			≥30 yrs	1	1.4 (0.0–8.1)		
Tornling *et al.* (1994), Stockholm, Sweden	Men working as firefighters for at least 1 yr, 1931–83	Enrollment records			**SMR**		
			Overall	12	1.2 (0.6–2.1)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Baris *et al.* (2001), Pennsylvania, USA	7789 firefighters employed 1925–86	Employee service records	Overall	24	0.9 (0.6–1.4)		
			Duration of employment		**SMR**		
			≤9 yrs	4	0.6 (0.2–1.5)		
			10–19 yrs	14	1.4 (0.8–2.4)		
			≥20 yrs	6	0.7 (0.3–1.4)		
			Hiring period				
			Hired before 1935	17	1.2 (0.7–1.9)		
			1935–44	4	0.6 (0.2–1.6)		
			After 1944	3	0.5 (0.2–1.7)		
			Number of runs				
			Low (<3323)	4	0.7 (0.3–1.8)		
			Medium (3323–5099)	1	0.3 (0.1–2.2)		
			High (5099+)	2	0.7 (0.2–2.6)		
Bates *et al.* (2001), New Zealand	All firefighters employed at least 1 yr, 1977–95	Employment registry			**SIR**		Only results for men were presented
			Overall	3	0.8 (0.2–2.2)		
Ma *et al.* (2005), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SMR**	Age, calendar year	
			Men	12	0.9 (0.5–1.4)		
			Women	0	–		
Ma *et al.* (2006), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SIR**	Age, calendar year	
			Men	14	0.5 (0.3–0.9)		
			Women	0	–		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Colon/Colorectal							
Eliopulos *et al.* (1984), Australia	990 firefighters employed 1939–78 Intestinal cancer	Western Australian Fire Brigade records	Overall	4	**SPMR** 1.6 (0.4–4.1)		
Vena & Fiedler (1987), New York State, USA	1867 male firefighters employed 1950–79 Colon	Death certificates	Overall	16	**SMR** 1.8 (1.1–3.0)		
Beaumont *et al.* (1991), California, USA	3066 male firefighters employed 1940–70 Intestine except rectum	Fire department records	Overall	24	**SMR** 1.0 (0.6–1.5)		
Grimes *et al.* (1991), Hawaii, USA	205 male firefighters Colon	Death certificates	Overall	2	**PRR** 0.9 (0.4–2.2)		Not clear if standardized by age and calendar period

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Demers *et al.* (1992a), Northwest USA	4546 male firefighters employed 1944–79 in selected Northwest cities Colon	Employment records	 Overall	 24	**SMR** 0.9 (0.5–1.3)	Age, calendar year	
Giles *et al.* (1993), Australia	2865 male firefighters employed 1917–89 Colorectal	Employment and union records, payrolls	 Overall	 9	**SIR** 1.4 (0.6–2.6)		
Guidotti (1993), Alberta, Canada	3328 firefighters employed 1927–87 Colon and rectum	Personnel files	 Overall	 14	**SMR** 1.6 (0.9–2.7)		
Aronson *et al.* (1994), Ontario, Canada	5373 male firefighters employed 1950–89 Colon	Employment records	 Overall	 11	**SMR** 0.60 (0.3–1.1)	Age, calendar year	

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Demers *et al.* (1994), Northwest, USA	2447 male firefighters employed 1974–89 Colon	Employment records			**SIR**		
			Overall	23	1.1 (0.7–1.6)		
			<10 yrs	2	0.8 (0.1–2.9)		
			10–19 yrs	2	0.7 (0.1–2.6)		
			20–29 yrs	15	1.1 (0.6–1.9)		
			≥30 yrs	4	1.5 (0.4–3.9)		
Tornling *et al.* (1994), Stockholm, Sweden	Men working as firefighters for at least 1 yr, 1931–83 Colon	Enrollment records			**SMR**		
			Overall	6	0.9 (0.3–1.9)		
Baris *et al.* (2001), Pennsylvania, USA	7789 firefighters employed 1925–86 Colon	Employee service records	Overall	64	1.5 (1.2–1.9)		
			Duration of employment		**SMR**		
			≤9 yrs	18	1.8 (1.1–2.8)		
			10–19 yrs	16	1.1 (0.7–1.8)		
			≥20 yrs	30	1.7 (1.2–2.4)		
			Hiring period				
			Hired before 1935	16	1.0 (0.6–1.6)		
			1935–44	28	2.0 (1.4–2.9)		
			After 1944	20	1.6 (1.0–2.5)		
			Number of runs				
			Low (<3323)	23	1.9 (1.3–2.9)		
			Medium (3323–5099)	16	2.2 (1.4–3.6)		
			High (5099+)	9	1.2 (0.6–2.4)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Bates *et al.* (2001), New Zealand	All firefighters employed at least 1 yr, 1977–95 Colon	Employment registry			**SIR**		
			Overall	7	0.6 (0.2–1.2)		
			Duration of employment				
			0–10 yrs	1	0.4 (0.0–2.3)		
			11–20 yrs	1	0.5 (0.0–2.6)		
			>20 yrs	5	1.4 (0.4–3.2)		
Ma *et al.* (2005), Florida, USA	34 796 male and 2017 female professional firefighters Colon	Employment records			**SMR**	Age, calendar year	
			Men	38	1.1 (0.8–1.6)		
			Women	1	2.3 (0.0–12.7)		
Ma *et al.* (2006), Florida, USA	34 796 male and 2017 female professional firefighters Colon	Employment records			**SIR**	Age, calendar year	
			Men	78	1.2 (0.9–1.5)		
			Women	2	2.3 (0.3–8.2)		
Rectum							
Vena & Fiedler (1987), New York State, USA	1867 male firefighters employed 1950–79	Death certificates			**SMR**		
			Overall	7	2.1 (0.8–4.3)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Beaumont *et al.* (1991), California, USA	3066 male firefighters employed 1940–70	Fire department records	Overall	13	1.5 (0.8–2.5)		
Demers *et al.* (1992a), Northwest, USA	4546 male firefighters employed 1944–79 in selected Northwest cities	Employment records	Overall	8	**SMR** 1.0 (0.4–1.9)	Age, calendar year	
Aronson *et al.* (1994), Ontario, Canada	5973 male firefighters employed 1950–1989 Rectum and rectosigmoid junction	Employment records	Overall	13	**SMR** 1.7 (0.9–2.9)		
Demers *et al.* (1994), Northwest USA	2447 male firefighters employed 1974–89	Employment records			**SIR**		
			Overall	12	1.0 (0.5–1.8)		
			<10 yrs	2	1.4 (0.2–4.9)		
			10–19 yrs	3	1.9 (0.4–5.4)		
			20–29 yrs	5	0.7 (0.2–1.6)		
			≥30 yrs	2	1.6 (0.2–5.6)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Tornling *et al.* (1994), Stockholm, Sweden	Men working as firefighters for at least 1 yr, 1931–83	Enrollment records			**SMR**		
			Overall	8	2.1 (0.9–4.1)		
Baris *et al.* (2001), Pennsylvania, USA	7789 firefighters employed 1925–86	Employee service records	Overall	14	1.0 (0.6–1.7)		
			Duration of employment		**SMR**		
			≤9 yrs	3	0.9 (0.3–2.7)		
			10–19 yrs	6	1.2 (0.5–2.6)		
			≥20 yrs	5	0.9 (0.4–2.2)		
			Hiring period				
			Hired before 1935	7	1.1 (0.5–2.2)		
			1935–44	3	0.7 (0.2–2.3)		
			After 1944	4	1.2 (0.5–3.2)		
			Number of runs				
			Low (<3323)	5	1.4 (0.5–3.3)		
			Medium (3323–5099)	1	0.5 (0.1–3.6)		
			High (5099+)	1	0.5 (0.1–3.9)		
Bates *et al.* (2001), New Zealand	All firefighters employed at least 1 yr, 1977–95	Employment registry			**SIR**		Only results for men were presented
			Overall	9	1.2 (0.5–2.2)		
			Duration of employment				
			0–10 yrs	2	1.2 (0.1–4.4)		
			11–20 yrs	2	1.4 (0.2–5.0)		
			>20 yrs	4	1.6 (0.4–4.1)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Ma *et al.* (2005), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SMR**	Age, calendar year	
			Men	7	0.9 (0.4–1.9)		
			Women	0			
Ma *et al.* (2006), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SIR**	Age, calendar year	
			Men	23	0.9 (0.6–1.3)		
			Women	1	5.3 (0.1–29.3)		
Skin							
Beaumont *et al.* (1991), California, USA	3066 male firefighters employed 1940–70	Fire department records			**IDR**	Age, calendar year	White men only
			Compared to police	6	1.1 (0.3–4.8)		
			Overall	7	1.7 (0.7–3.5)		
Demers *et al.* (1992a), Northwest, USA	4546 male firefighters employed 1944–79 in selected Northwest cities	Employment records			**SMR**	Age, calendar year	
			Overall	6	1.0 (0.4–2.1)		
Guidotti (1993), Alberta, Canada	3328 firefighters employed 1927–87	Personnel files			**SMR**		
			Overall	0	0 (0–3.3)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Tornling *et al.* (1994), Stockholm, Sweden	Men working as firefighters for at least 1 yr, 1931–83; Non-melanoma skin cancer	Enrollment records			**SMR**		
			Overall	5	1.5 (0.5–3.5)		
Baris *et al.* (2001), Pennsylvania, USA	7789 firefighters employed 1925–86	Employee service records	Overall	10	1.2 (0.6–2.2)		
			Duration of employment		**SMR**		
			≤9 years	2	0.8 (0.2–3.0)		
			10–19 years	5	1.7 (0.7–4.1)		
			≥20 years	3	1.1 (0.3–3.3)		
			Hiring period				
			Hired before 1935	3	1.5 (0.5–4.5)		
			1935–44	1	0.4 (0.1–3.0)		
			After 1944	6	1.5 (0.7–3.3)		
			Number of runs				
			Low (<3323)	1	0.4 (0.1–2.5)		
			Medium (3323–5099)	5	3.1 (1.3–7.5)		
			High (5099+)	1	0.5 (0.1–3.8)		
Ma *et al.* (2005), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SMR**	Age, calendar year	
			Men	17	0.9 (0.5–1.4)		
			Women	0	–		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Ma *et al.* (2006), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SIR**	Age, calendar year	
			Men	99	1.2 (1.0–1.4)		
			Women	5	3.0 (1.0–7.0)		
Melanoma							
Demers *et al.* (1992b), Northwest, USA	4528 male firefighters employed 1944–79	Employment records			**SIR**		Data for firefighters and police combined
				15	1.2 (0.7–2.0)		
					SMR		
				5	1.6 (0.5–3.8)		
Giles *et al.* (1993), Australia	2865 male firefighters employed 1917–89	Employment and union records, payrolls			**SIR**		
			Overall	5	1.1 (0.4–2.5)		
Aronson *et al.* (1994), Ontario, Canada	5373 male firefighters employed 1950–1989	Employment records			**SMR**		
			Overall	2	0.7 (0.1–2.6)		
Demers *et al.* (1994), Northwest, USA	2447 male firefighters employed 1974–89	Employment records			**SIR**		
			Overall	9	1.2 (0.6–2.3)		
			<10 years	0	0 (0.0–2.6)		
			10–19 years	4	2.3 (0.6–5.8)		
			20–29 years	4	1.1 (0.3–2.7)		
			≥30 years	1	2.4 (0.1–13.0)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Tornling *et al.* (1994), Stockholm, Sweden	Men working as firefighters for at least 1 yr, 1931–83 Malignant melanoma	Enrollment records			**SMR**		
			Overall	2	0.8 (0.09–2.9)		
Bates *et al.* (2001), New Zealand	All firefighters employed at least 1 yr, 1977–95	Employment registry			**SIR**		Only results for men were presented
			Overall	23	1.3 (0.8–1.9)		
			0–10 years	7	1.7 (0.7–3.5)		
			10–19 years	6	1.8 (0.6–3.8)		
			>20 years	6	1.7 (0.6–3.6)		
Prostate							
Vena & Fiedler. (1987), New York State, USA	1867 male firefighters employed 1950–79	Death certificates			**SMR**	Age, calendar year	
			Overall	5	0.7 (0.2–1.7)		
Beaumont *et al.* (1991), California, USA	3066 male firefighters employed 1940–70	Fire department records			**SMR**	Age, calendar year	
			Overall	8	0.4 (0.2–0.8)		
Grimes *et al.* (1991), Hawaii, USA	205 male firefighters	Death certificates			**PRR**	Age, calendar year	Not clear if standardized by age and calendar period
			Overall	4	2.6 (1.4–5.0)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Demers *et al.* (1992a), Northwest, USA	4546 male firefighters employed 1944–79 in selected Northwest cities	Employment records			**SMR**	Age, calendar year	
			Overall	30	1.3 (0.9–1.9)		
			<10 years	3	2.4 (0.5–7.1)		
			10–19 years	2	1.1 (0.1–4.1)		
			20–29 years	14	1.2 (0.7–2.1)		
			≥30 years	11	1.4 (0.7–2.4)		
					IDR		
			Compared to police	30	1.4 (0.7–2.9)		
Giles *et al.* (1993), Australia	2865 male firefighters employed 1917–89	Employment and union records			**SIR**	Age, calendar year	
			Overall	5	2.1 (0.7–4.9)		
Guidotti (1993), Alberta, Canada	3328 firefighters employed 1927–87	Personnel files			**SMR**	Age, calendar year	
			Overall	8	1.5 (0.6–2.9)		
Aronson *et al.* (1994), Ontario, Canada	5373 male firefighters employed 1950–89	Employment records			**SMR**	Age, calendar year	
			Overall	16	1.3 (0.8–2.2)		
			Duration of employment				
			<15 years	1	1.6 (0.1–9.0)		
			15–29 years	5	2.4 (0.8–5.7)		
			30+ years	9	1.0 (0.4–1.8)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Demers *et al.* (1994), Seattle & Tacoma, USA	2447 male firefighters, employed 1974–89	Employment records			**SIR**	Age, calendar year	Subpopulation of Demers *et al.*, (1992)
			Overall	66	1.4 (1.1–1.7)		
			<10 years	7	1.4 (0.6–2.8)		
			10–19 years	6	1.2 (0.4–2.6)		
			20–29 years	47	1.5 (1.1–2.0)		
			≥30 years	6	0.9 (0.3–1.9)		
					RR		
			Compared to police	66	1.1 (0.7–1.8)		
Tornling *et al.* (1994), Stockholm, Sweden	Men working as firefighters for at least 1 yr, 1931–83	Enrollment records			**SMR**	Age, calendar year	
			Overall	14	1.21 (0.7–2.0)		
Baris *et al.* (2001), Pennsylvania, USA	7789 firefighters employed 1925–86	Employee service records			**SMR**	Age, calendar year	
			Overall	31	1.0 (0.7–1.4)		
			Duration of employment				
			≤9 years	15	2.4 (1.4–3.9)		
			10–19 years	5	0.5 (0.2–1.1)		
			≥20 years	11	0.7 (0.4–1.3)		
			Hired before 1935	12	0.8 (0.4–1.3)		
			1935–44	14	1.4 (0.8–2.3)		
			After 1944	5	0.8 (0.3–2.0)		
			Number of runs				
			Low (<3323)	10	1.3 (0.7–2.5)		
			Medium (3323–5099)	3	0.7 (0.2–2.0)		
			High (5099+)	6	1.4 (0.6–3.2)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Bates *et al.* (2001), New Zealand	All firefighters employed at least 1 yr, 1977–95	Employment registry			**SIR**	Age, calendar year	Only results for men were presented
			Overall	11	1.1 (0.5–1.9)		
			Duration of employment				
			0–10 years	3	1.5 (0.3–4.3)		
			11–20 years	1	0.6 (0.1–3.3)		
			>20 years	1	0.3 (0.1–1.6)		
Ma *et al.* (2005), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SMR**	Age, calendar year	
			Overall	21	1.1 (0.7–1.7)		
Ma *et al.* (2006), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SIR**	Age, calendar year	Same population as Ma *et al.*, (2005)
			Overall	209	1.1 (1.0–1.4)		
Testis							
Giles *et al.* (1993), Australia	2865 male firefighters employed 1917–89	Employment and union records, payrolls			**SIR**	Age, calendar year	
			Overall	2	1.2 (0.1–4.2)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Aronson *et al.* (1994), Ontario, Canada	5373 firefighters employed 1950–89	Employment records			**SMR**	Age, calendar year	
			Overall	3	2.5 (0.5–7.4)		
			Duration of employment				
			<15 years	3	3.7 (0.8–10.7)		
			15–29 years	0	0.0 (0.0–14.2)		
			30+ years	0	0.0 (0.0–36.9)		
Bates *et al.* (2001), New Zealand	All firefighters employed at least 1 yr, 1977–95 Testicular	Employment registry			**SIR**	Age, calendar year	Only results for men were presented
			Overall	11	1.6 (0.8–2.8)		
			Duration of employment				
			0–10 years	3	1.6 (0.3–4.5)		
			11–20 years	4	3.5 (1.0–9.0)		
			>20 years	2	4.1 (0.5–14.9)		
Ma *et al.* (2006), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SIR**	Age, calendar year	
			Men	54	1.6 (1.2–2.1)		
Brain / CNS							
Musk *et al.* (1978), Massachusetts, USA	5655 male firefighters employed 1915–75	Death certificates			**SMR**		Confidence interval not provided, not calculated
				8	1.0		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Vena & Fiedler (1987), New York State, USA	1867 male firefighters employed 1950–79 Brain	Death certificates			**SMR**		
			Overall	6	2.4 (0.9–5.1)		
Heyer *et al.* (1990), Washington, USA	2289 male firefighters employed at least 1 yr, 1945–80; follow-up until 1983	Employment records			**SMR**		
			Overall	3	1.0 (0.2–2.8)		
			Duration of employment				
			<15 years	2	1.84 (0.22–6.49)		
			15–29 years	1	0.86 (0.10–3.11)		
			30+ years	0	5.03 (1.04–14.70)		
Beaumont *et al.* (1991), California, USA	3066 male firefighters employed 1940–70	Fire department records	Overall	5	0.8 (0.3–1.9)		
Grimes *et al.* (1991), Hawaii, USA	205 male firefighters Brain	Death certificates			**PRR**		Not clear if standardized by age and calendar period
			Overall	2	3.8 (1.2–11.7)		
Demers *et al.* (1992a), Northwest, USA	4546 male firefighters employed 1944–79 in selected Northwest cities	Employment records			**SMR**		
			Overall	18	2.1 (1.2–3.3)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Guidotti (1993), Alberta, Canada	3328 firefighters employed 1927–87 Brain	Personnel files			**SMR**		
			Overall	3	1.5 (0.3–4.3)		
Aronson *et al.* (1994), Ontario, Canada	5373 male firefighters employed 1950–89	Employment records			**SMR**		
			Overall	14	2.0 (1.1–3.4)		
Demers *et al.* (1994), Northwest USA	2447 male firefighters employed 1974–89 Brain	Employment records			**SIR**		
			Overall	4	1.1 (0.3–2.9)		
			<10 years	1	1.6 (0.0–8.8)		
			10–19 years	0	0 (0.0–4.6)		
			20–29 years	3	1.6 (0.3–4.6)		
			≥30 years	0	0 (0.0–16)		
Tornling *et al.* (1994), Stockholm, Sweden	Men working as firefighters for at least 1 yr, 1931–83 Brain	Enrollment records			**SMR**		
			Overall	5	2.8 (0.9–6.5)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Baris *et al.* (2001), Pennsylvania, USA	7789 firefighters employed 1925–86 Brain	Employee service records	Overall	8	0.6 (0.3–1.2)		
			Duration of employment		**SMR**		
			≤9 years	2	0.5 (0.1–1.9)		
			10–19 years	2	0.4 (0.1–1.8)		
			≥20 years	4	0.9 (0.4–2.5)		
			Hiring period				
			Hired before 1935	1	0.4 (0.1–2.6)		
			1935–1944	3	0.7 (0.2–2.2)		
			After 1944	4	0.7 (0.3–1.8)		
			Number of runs				
			Low (<3323)	3	0.6 (0.2–1.9)		
			Medium (3323–5099)	2	0.8 (0.2–3.1)		
			High (5099+)	2	0.7 (0.2–2.9)		
Bates *et al.* (2001), New Zealand	All firefighters employed at least 1 year, 1977–95 Brain	Employment registry			**SIR**		Only results for men were presented
			Overall	5	1.3 (0.4–3.0)		
Ma *et al.* (2005), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SMR**	Age , calendar year	
			Men	13	0.7 (0.4–1.1)		
			Women	0	–		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Ma *et al.* (2006), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SIR**	Age, calendar year	
			Men	14	0.6 (0.3–1.0)		
			Women	0			
Non-Hodgkin lymphoma							
Giles *et al.* (1993), Australia	2865 male firefighters employed 1917–89	Employment and union records			**SIR**	Age, calendar period	
			Overall	4	1.9 (0.5–4.7)		
Aronson *et al.* (1994), Ontario, Canada	5373 male firefighters employed 1950–89 Lymphosarcoma	Employment records			**SMR**	Age, calendar year	
			Overall	3	2.0 (0.4–6.0)		
Demers *et al.* (1994), Seattle & Tacoma, USA	2447 male firefighters employed 1974–89	Employment records			**SIR**	Age, calendar year	
			Overall	7	0.9 (0.4–1.9)		
			Duration fire fighting				
			<10 years	1	0.9 (0.4–4.9)		
			10–19 years	1	0.6 (0.1–4.5)		
			20–29 years	5	1.2 (0.4–2.7)		
			30+ years	0	0.0 (0.0–5.8)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Baris *et al.* (2001), Pennsylvania, USA	7789 firefighters employed 1925–86	Employee service records	Overall	10	1.4 (0.9–2.2)	Age, calendar year	
			Duration of employment		**SMR**		
			≤9 years	6	1.5 (0.7–3.3)		
			10–19 years	5	1.0 (0.4–2.5)		
			≥20 years	9	1.7 (0.9–3.3)		
			Hiring period				
			Hired before 1935	3	0.7 (0.2–2.2)		
			1935–1944	10	2.2 (1.2–4.1)		
			After 1944	7	1.3 (0.6–2.7)		
			Number of runs				
			Low (<3323)	11	2.4 (1.3–4.3)		
			Medium (3323–5099)	4	1.6 (0.6–4.1)		
			High (5099+)	2	0.7 (0.2–2.9)		
Ma *et al.* (2006), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SIR**	Age, calendar year	
			Men	15	1.1 (0.6–1.8)		
			Women	1	33.3 (0.4–185)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Multiple myeloma							
Heyer *et al.* (1990), Seattle, USA	2289 male firefighters employed at least 1 yr, 1945–80; follow-up until 1983	Employment records			**SMR**	Age, calendar year	
			Overall	3	2.25 (0.47–6.60)		
			Duration of employment				
			<15 years	0	0 (0–15.96)		
			15–29 years	1	1.11 (0.03–6.21)		
			30+ years	2	9.89 (1.20–35.71)		
Demers *et al.* (1992a), Seattle, Portland & Tacoma, USA	4546 male firefighters employed at least 1 yr, 1944–79; follow-up until 1989	Employment records			**RR** 1.9 (0.4–8.4)	Age, calendar year	A police cohort used as a reference group. Reference rates for US white men were obtained from the National Institute for Occupational Safety and Health. Overlap with Heyer *et al.* (1990)
Aronson *et al.* (1994), Ontario, Canada	5373 male firefighters employed 1950–89	Employment records	Overall	1	**SMR** 0.4 (0.0–2.2)	Age, calendar year	

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Demers *et al.* (1994), Seattle & Tacoma, USA	2447 male firefighters employed 1974–89	Employment records			**SIR**	Age, calendar year	Overlap with Demers, 1992
				2	0.7 (0.1–2.6)		
Baris *et al.* (2001), Pennsylvania, USA	7789 male firefighters employed 1925–86	Employee service records			**SMR**	Age, calendar year	
			Overall	10	1.7 (0.9–3.1)		
			Duration of employment				
			≤9 years	1	0.7 (0.1–5.2)		
			10–19 years	3	1.5 (0.5–4.7)		
			≥20 years	6	2.3 (1.0–5.2)		
			Hiring period				
			Hired before 1935	4	2.1 (0.8–5.5)		
			1935–1944	3	1.4 (0.5–4.4)		
			After 1944	3	1.6 (0.5–4.8)		
			Number of runs				
			Low (<3323)	1	0.6 (0.9–4.1)		
			Medium (3323–5099)	3	2.7 (0.9–8.4)		
			High (5099+)	2	1.7 (0.4–6.9)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Leukaemia							
Musk *et al.* (1978), Massachusetts, USA	5655 male firefighters employed 1915–75 Lymphatic and haemapoietic	Death certificates	Overall	22	**SMR** 0.6		Confidence interval not provided, not calculated
Heyer *et al.* (1990), Washington, USA	2289 male firefighters employed at least 1 yr, 1945–80; follow-up until 1983 Leukaemia and aleukaemia	Employment records	Overall	7	**SMR** 1.7 (0.7–3.6)		
Beaumont *et al.* (1991), California, USA	3066 male firefighters employed 1940–70 Leukaemia and aleukaemia	Fire department records	Overall	6	0.6 (0.2–1.3)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Demers *et al.* (1992a), Northwest USA	4546 male firefighters employed 1944–79 in selected Northwest cities	Employment records		15	**SMR** 1.3 (0.7–2.1)		
Demers *et al.* (1992b), Northwest USA	4528 male firefighters employed 1944–79	Employment records		10 8	**SIR** 1.05 (0.5–1.9) **SMR** 1.3 (0.5–2.5)		Data for firefighters and police combined
Guidotti (1993), Alberta, Canada	3328 firefighters employed 1927–87 Leukaemia, lymphoma, myeloma	Personnel files	Overall	10	**SMR** 1.3 (0.6–2.3)		
Aronson *et al.* (1994), Ontario, Canada	5995 firefighters employed 1950–89 Lymphatic leukaemia	Employment records	Overall	4	**SMR** 1.9 (0.5–4.9)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Demers *et al.* (1994), Northwest USA	2447 male firefighters employed 1974–89	Employment records			**SIR**		
			Overall	6	1.0 (0.4–2.1)		
			<10 years	0	0 (0.0–4.4)		
			10–19 years	2	1.9 (0.2–6.8)		
			20–29 years	4	1.1 (0.3–2.8)		
			≥30 years	0	0 (0.0–5.4)		
Baris *et al.* (2001), Pennsylvania, USA	7789 firefighters employed 1925–86	Employee service records	Overall	15	0.8 (0.5–1.4)		
			Duration of employment		**SMR**		
			≤9 years	5	0.9 (0.4–2.3)		
			10–19 years	7	1.1 (0.5–2.4)		
			≥20 years	3	0.5 (0.2–1.4)		
			Hiring period				
			Hired before 1935	2	0.3 (0.1–1.3)		
			1935–1944	6	1.1 (0.5–2.4)		
			After 1944	7	1.1 (0.5–2.3)		
			Number of runs				
			Low (<3323)	5	0.8 (0.4–2.0)		
			Medium (3323–5099)	4	1.4 (0.5–3.6)		
			High (5099+)	4	1.3 (0.5–3.6)		

Table 2.2 (contd)

Reference, location, name of study	Cohort description	Exposure assessment	Exposure categories	No. of cases/ deaths	Relative risk (95% CI)*	Adjustment for potential confounders	Comments
Ma *et al.* (2005), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SMR**	Age, calendar year	
			Men	14	0.8 (0.5–1.4)		
			Women	0	–		
Ma *et al.* (2006), Florida, USA	34 796 male and 2017 female professional firefighters	Employment records			**SIR**	Age, calendar year	
			Men	20	0.8 (0.5–1.2)		
			Women	0	–		

IDR, incidence density ratio; PRR, proportional risk ratio; SIR, standardized incidence ratio; SMR, standardized mortality ratio; SPMR, standardized proportional mortality ratio; yr, year

Deschamps *et al.* (1995) investigated all professional male members of the Brigade des Sapeurs-Pompiers de Paris (*n* = 830) who served for a minimum of 5 years as of January 1st, 1977. They were monitored for a 14-year period, with follow-up terminating on January 1st, 1991. Cause-specific mortality rates in these firefighters were compared with national mortality data provided by the Institut National de la Santé et de la Recherche Médicale. To assess the occupational exposure as a firefighter, data were collected on duration of employment as an active duty firefighter (as opposed to office work). These 830 firefighters accrued a total of 11 414 person–years of follow-up. Follow-up appears to have been 100% complete. There were 32 deaths in the cohort during the 14-year period of follow-up. When compared to the average French male, they were found to have a far lower overall mortality (SMR, 0.52 [95% CI: 0.35–0.75]). None of the cause-specific SMRs was significant. However, a greater number of deaths than expected was observed for genito-urinary cancer (SMR, 3.29) [based on one bladder cancer, and one testicular cancer], and digestive cancer (SMR, 1.14).

Baris *et al.* (2001) conducted a retrospective cohort mortality study among 7789 firefighters in Philadelphia, Pennsylvania, USA, on males employed during 1925–1986. Vital status was ascertained up until 1986. SMRs and 95% CI were calculated with expected numbers of deaths in the United States white male population, as the overwhelming majority of firefighters were white. Occupational exposure histories were abstracted from detailed records maintained by the Philadelphia Fire Department, and a job–exposure matrix was created for each firefighter. To estimate exposure–response relationships, the study used this matrix to compare mortality among groups of firefighters defined by the estimated number of career runs. There were 2220 deaths and a total of 6.2% of the cohort was lost to follow-up. In comparison with white males in the United States, firefighters had a similar mortality from all causes of death combined (SMR, 0.96), and all cancers (SMR, 1.10). Statistically significant excess risks were observed for colon cancer (SMR, 1.51). The risks of mortality from colon cancer (SMR, 1.68), kidney cancer (SMR, 2.20), non-Hodgkin lymphoma (SMR, 1.72), multiple myeloma (SMR, 2.31), and benign neoplasms (SMR, 2.54) were increased in firefighters with at least 20 years of service.

Bates *et al.* (2001) conducted a historical cohort study of mortality and cancer incidence in all remunerated New Zealand firefighters, who served during 1977–1995. Ascertainment of employment was through a registry maintained by the United Fire Brigades Association of New Zealand. The final cohort comprised 4221 male firefighters. To assess the occupational exposure as a firefighter, data were collected on duration of employment. The 4221 male firefighters in this cohort accrued a total of 58 709 person–years of follow-up. Follow-up was successful in tracing 93.5%. There were 117 deaths up until 1995. Cancer incidence was ascertained during 1977–1996. The SIR for all cancers was 0.95. For most sites, no excesses were observed. The only cancer for which this study provided evidence of an increased risk was testicular cancer. Eleven testicular cancers were observed versus 7.1 expected (SIR, 1.55; 95% CI: 0.8–2.8). For the years 1990–1996, the SIR for testicular cancer was 3.0 (95% CI: 1.3–5.9).

Ma *et al.* (2005) examined age- and gender-adjusted mortality rates of 36 813 professional firefighters employed during 1972–1999 in Florida, USA, and compared those with that of the Florida general population. The study population consisted of 34 796 male and 2017 female professional firefighters. The racial/ethnic composition was caucasian (90.1%), hispanic (7%), and black (6.5%). Employment as a firefighter was ascertained from employment records in the Florida State Fire Marshall Office. Surrogate information on occupational exposures in firefighting was collected by examining the year of certification and duration of employment as a firefighter. No information was collected on smoking histories. A total of 1411 male and 38 female deaths with known causes were identified in this cohort. In male firefighters, a deficit of overall mortality from cancer was observed (SMR, 0.85). Excess risks were observed for male breast cancer (SMR, 7.41; 95% CI: 1.99–18.96), and thyroid cancer (SMR, 4.82; 95% CI: 1.30–12.34), each based on four cases. Mortality from bladder cancer was increased and approached statistical significance (SMR, 1.79; 95% CI: 0.98–3.00). Female firefighters had similar overall cancer mortality patterns to Florida women (SMR, 1.03), but the numbers were small for specific cancer sites.

In a further analysis of the same cohort, Ma *et al.* (2006) determined the relative cancer risk for firefighters in the State of Florida compared with the Florida general population. Employment as a firefighter was ascertained from employment records in the Florida State Fire Marshall Office. Cancer incidence was determined through linkage to the Florida Cancer Data System, a statewide cancer registry estimated to capture 98% of cancers in Florida residents. No pathological verification of cancer diagnoses was undertaken. A total of 970 male and 52 female cases of cancer were identified; 6.7% of the cohort were lost to follow-up. Male firefighters had significantly increased incidence rates of cancers of the bladder (SIR, 1.29; 95% CI: 1.01–1.62), testis (SIR, 1.60; 95% CI: 1.20–2.09), and of the thyroid (SIR, 1.77; 95% CI: 1.08–2.73). Female firefighters had significantly increased incidence rates of overall cancer (SIR, 1.63; 95% CI: 1.22–2.14), cervical (SIR, 5.24; 95% CI: 2.93–8.65) and thyroid cancers (SIR, 3.97; 95% CI: 1.45–8.65), and Hodgkin disease (SIR, 6.25; 95% CI: 1.26–18.26).

2.2 Case–control studies

Case–control studies have been used to examine the risk of firefighting and its association with various types of cancers. In all but one of these studies, ten or fewer firefighters were included in the case and/or control group. Several studies combined broad occupational categories with heterogeneous exposures such as firefighter and fireman, with the latter not necessarily working as a firefighter. These types of studies may result in exposure misclassification. Even within specific occupational groups such as firefighters, all would not have the same intensity or type of exposures. The magnitude of this form of misclassification is unknown, but it is likely that the resulting misclassification will be non-differential with regard to cases and controls. Another limitation to case–control studies is that cases may be more likely than controls to remember jobs of shorter duration. Those jobs in the more distant past may be more likely recalled by cases than controls resulting in differential bias away from the null. Alternatively, in several of the reported studies, cases were more likely than the controls to provide proxy interviews by their survivors rather than by the cases themselves. Because of the relatively few studies available for individual organ sites, the studies were grouped into four categories including urogenital, brain and central nervous system, larynx and lung, and other.

2.2.1 *Cancers of the urogenital system*

Four cancers of the urogenital organs in relation to employment as a firefighter were considered (Tables 2.3 and 2.6).

Delahunt *et al.* (1995) examined pathologically confirmed incident renal cell carcinomas the New Zealand Cancer Registry during the period 1978–1986. The registry included 95% of those patients diagnosed and treated in both the public and private sector. At time of registration, the current or most recent occupation was recorded. Additional information collected included age, and smoking habits. Renal cell carcinomas with an ICD-9 code of 189.0 (malignant neoplasm of the kidney, excluding the renal pelvis) were evaluated. The control groups were a random sample of registrations drawn from all cases over 20 years of age, having primary tumours from sites other than the urinary tract registered during the same time period. There were a total of 710 male cases and 12 756 controls. There were 52 cases and 737 controls under the occupational classification of "Service" which included firefighters and five other occupational groups. The relative risk for firefighters was 4.7 (95% CI: 2.5–8.9).

Bates (2007) (see Table 2.6) conducted a registry-based case–control study using the California Cancer Registry. Anonymized records of all male cancers for the period 1988–2003 were collected. To identify firefighters, the occupation and industry fields were searched for titles including fire, firefighter, fire fighter, fireman, fire man, and fire chief. If the subjects indicated that they did not carry out firefighting activities, they were not considered. A total of 16 cancer organ sites were examined including kidney, bladder, prostate, and testis. For each analysis, all other cancers were used as controls except for those cancers shown in the initial analysis that had demonstrated a firefighting etiology; these included cancers of the lung, bronchus, bladder, prostate, colorectum, and skin melanomas. Analysis was limited to males aged 21–80 at time of diagnosis. There were 3659 firefighters and 800 448 controls in the analysis after exclusion of 13% of the files ($n = 140\,000$) with no recorded occupation or industry. Logistic regression analyses were performed for each cancer type for which there had been more than 50 cancers recorded in firefighters. This was not done for for cancer of the thyroid ($n = 32$ cases) or multiple myeloma ($n = 37$ cases) as these two were based on prior hypotheses.

Table 2.3. Case–control studies of the urogenital system

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of exposed cases	Odds Ratio (95% CI)	Adjustment for potential confounders	Comments
Delahunt *et al.* (1995) New Zealand, 1978–86	Renal cell (189.0)	Total number of renal cell carcinomas for all occupations –710 men (Cancer Registry); coverage of 95% incident cases including pathology coding. Occupational code for 86.2%; 5 categories of service workers including firefighters; in which, 52 cases with an unknown number of firefighters	Random sample drawn from all cancer cases except renal cell carcinoma aged over 20 years, having primary tumours from sites other than the urinary tract. 12 756 (all men, Cancer Registry); matched by age, and registration period. 737 controls for category of service workers	Occupation code used to identify employment	 Firefighters unadjusted Firefighters age- and smoking-adjusted	 NR NR	 3.51 (2.09–5.92) 4.69 (2.47–8.93)	Age, smoking	Firefighters likely represented ~10 cases although exact numbers not reported

Table 2.3 (contd)

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of exposed cases	Odds Ratio (95% CI)	Adjustment for potential confounders	Comments
Krstev *et al*. (1998) Atlanta, Detroit and 10 counties in New Jersey, USA 1986–89	Prostate	Population-based incident cases from registry; 981 (479 blacks and 502 Caucasians) aged 40–79 years; cases selected by random sample to ensure broad distribution by age and race, a varying proportion of cases selected by random sampling. Histologically confirmed. Response rate not provided but 6 cases and 17 controls with no employment data	1315 (594 blacks and 721 Caucasians) population-based controls selected aged <65 years by random-digit dialling, and >65 selected by random sampling from computerized records of the Health Care Financing for each geographic area administration; matched by age, sex and race	In-person interviews by trained interviewers	Firefighting and prevention		3.85 (1.34–11.10)	Age, sex and race	Small number of cases and controls
					– All firefighting	10	3.34 (1.13–9.91)		
					Duration of firefighting				
					<5 years	2	–		
					5–19 years	3	1.66 (0.33–8.36)		
					≥20 years	5	3.94 (0.76–25.60)		
							P for trend=0.07		

Table 2.3 (contd)

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of exposed cases	Odds Ratio (95% CI)	Adjustment for potential confounders	Comments
Stang *et al*. (2003) Bremen, Essen, Hamburg, Saarbrücken, and Saarland, Germany, 1995–97	Testicular or extragonadal germ cell tumours	269 cases from an active reporting system of clinical and pathological departments; aged 15–69 years; 78% response rate; histologically confirmed. 4 cases (1.5%) were firefighters	797 controls selected randomly from mandatory registries of residence; 57% response rate; matched by age and region of residence 3 controls (0.4%) were fireghters	In-person and telephone interviews conducted by trained interviewers	Worked as a firefighter Ever ≥10 years of duration Work began ≥5 years before diagnosis	 4 2 3	 4.3 (0.7–30.5) 3.0 (0.2–45.5) 3.1 (0.4–24.4)	History of cryptorchidism	Number of firefighter case and controls too low for precise effect but trend is strong

Table 2.3 (contd)

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of exposed cases	Odds Ratio (95% CI)	Adjustment for potential confounders	Comments
Gaertner *et al.* (2004) Newfoundland, Prince Edward Island, Nova Scotia, Manitoba, Alberta, Saskatchewan and British Columbia, Canada, 1994–97	Bladder	Incident cases identified in Cancer Registries: 887 cases from Canadian provincial cancer registries; aged 20–74 years; 58 % male response rate, and 61% female response rate; 8 male firefighters	2847 population-based controls selected by random-digit dialling to recruit controls in Newfoundland and Alberta, and random sampling from the provincial health insurance plan database for other locations; 59% male response rate, and 65% female response rate; matched by age and sex 13 male controls	Mailed questionnaires and telephone follow-ups	Firefighter males only	8	1.51 (0.59–3.84)	Adjusted for age, province, race, smoking, ex-smoking, consumption of fruit, fried food and coffee	No females were included in the analysis
					Duration of firefighting in years				
					>1–5	3	2.00 (0.43–9.49)		
					>5–15	1	0.86 (0.71–8.93)		
					>15	4	1.36 (0.36–5.16)		

NR, not reported

Logistic regression analyses adjusted for 5-year age categories, 4-year categories from date of diagnosis, five ethnic categories and five categories of an indicator of socioeconomic status. A total of 101 firefighters with a diagnosis of cancer of the kidney or renal pelvis were assessed, and the OR was 1.07 (95% CI: 0.87–1.31), adjusted for age, calendar period of diagnosis, race, and an indicator of socioeconomic status for the census block of residence.

Krstev *et al.* (1998) investigated incident prostate cancer cases in the USA using population-based cancer registries for Atlanta Georgia and Detroit Michigan, and for ten counties in the state of New Jersey during 1986–1989. Histologically confirmed cases were identified from pathology and outpatient records at hospitals included in these registries. Cases were selected by random sampling among the total number of cases identified in each age–race category. [Three additional cancer sites were investigated but not reported including oesophagus, pancreas, and multiple myeloma, and no published articles were located regarding these cancers.] Control subjects were proportional to the age, sex, and race distribution of the cases. Controls younger than 65 years of age were selected through random-digit dialling. Older controls were systematically selected by random sampling from computerized records of the Health Care Financing Administration stratified by three age groups, and race (african american or caucasian for each geographic area). Cases and controls were interviewed in person. There were 981 cases and 1315 controls analysed using unconditional logistic regression adjusted for age (< 60, 60–69, 70+), study site, and race. A total of ten cases and five controls were classified as firefighting (SOC 512.3). The overall adjusted OR for prostate cancer was 3.85 (95% CI: 1.34–11.10), for caucasians only (nine cases and three controls) 4.75 (1.26–18.00), and for african americans (three cases and two controls), 2.64 (0.43–16.20).

Bates (2007) evaluated 1144 firefighters diagnosed with cancer of the prostate (cohort described above for cancer of the kidney), and found an adjusted OR of 1.22 (95% CI: 1.12–1.33).

Stang *et al.* (2003) examined the risk of testicular cancer or extragonadal germ cell tumours during 1995–1997 in five German regions. Cases were reported through an active reporting system. A pathologist derived histological evaluations for 95% of the cases. Interviews were conducted with 269 of the 353 eligible cases, with a response rate of 78% including the two surrogate interviews. Controls were randomly selected from mandatory registries of residence. Approximately two controls were age- and region-matched for the cases between the ages of 15–34 years. Four controls were matched for those cases aged 35–69 to increase study power related to the fewer number of cases in this older age group. The response rate in the controls was 57%, with 918 interviewed (eight surrogate) of 1982 eligible subjects. Each job held for at least 6 months was recorded including job tasks and hours per week worked. These jobs were coded according to the International Standard Classification of Occupation. Conditional logistic regression models were calculated with matching factors including 5-year age groups, and geographic region. The adjusted ORs for 'ever' versus 'never' employed as a firefighter were 4.3 (95% CI: 0.7–30.5, four cases and three controls); for working as a firefighter ≥ 10 years, 3.0 (95% CI: 0.2–45.5, two cases and two controls); and for employment ≥ 5 years before the 'reference' date [date of diagnosis], 3.1 (95% CI: 0.4–24.4, three cases and three controls).

Bates (2007) also evaluated 70 firefighters diagnosed with cancer of the testis (SEER code 28020, cohort described above for cancer of the kidney), and found an adjusted OR of 1.54 (95% CI: 1.18–2.02).

Gaertner *et al.* (2004) reported on incident cases of bladder cancer with a histological confirmation, identified through the National Enhanced Cancer Surveillance System programme in seven Canadian provinces. The cases were adults aged 20–74, identified during 1994–1997 and interviewed 2–5 months after diagnosis. Random selections of population controls were included in the programme by frequency-matching age and gender to all cancer cases. Random digit dialling was used during the 1996 calendar year to recruit controls living in Newfoundland and Alberta, while all other provinces used a random sample from the provincial health insurance database. Native Indians and subjects in the military were excluded from the study. Mailed questionnaires with telephone follow-up, as necessary, were used to gather data regarding sociodemographics, occupational history, smoking history, dietary habits, and specific agent exposures. The response rates for the male and female bladder cancer cases were 66% and 72%, respectively, and for the controls, 59% and 65%, respectively. The overall analysis included 887 cases and 2847 controls. In the analysis of firefighters, eight male cases and 13 male controls were considered. the Standardized Occupational Classification system was used to code occupations, with up to 12 occupations coded per person. Data analysis also included demographic information provided from the interviews. An unconditional logistic regression analysis was used adjusting for age, province, race, smoking, ex-smoking, and consumption of fruit, fried food, and coffee. For the analysis of 'ever' or 'never' worked as a firefighter for more than one year, an elevated OR of 1.51 (95% CI: 0.59–3.84) was found. When stratified by duration of employment as a firefighter, the ORs were: 2.0 (95% CI: 0.43–9.49) for > 1–5 years (three cases and four controls); 0.86 (95% CI: 0.708–8.93) for > 5–15 years (one case and three controls); and 1.36 (95% CI: 0.36–5.16) for > 15 years (four cases and six controls).

Bates (2007) assessed 174 firefighters diagnosed with cancer of the bladder (SEER code 29010, cohort described above for cancer of the kidney and Table 2.6), and found an adjusted OR of 0.85 (95% CI: 0.72–1.00).

2.2.2 *Cancer of the brain*

Four studies on brain cancer in relation to firefighting were considered, all from the USA (Tables 2.4 and 2.6).

Brownson *et al.* (1990) evaluated brain cancers using the Missouri Cancer registry. Cancer cases from public and private hospitals have been collected since 1972, and reporting has been mandated since 1984. The group of cases comprised Caucasian males diagnosed with histologically confirmed brain and other central nervous system cancers (ICD codes 191 and 192). Four controls were randomly selected and frequency-matched from all Caucasian male patients diagnosed with cancers during the same time period. Control group cancers included cancers of the lip, oral cavity and pharynx, digestive organs and peritoneum, respiratory system, skin, bones and connective tissue, genitourinary system, and leukaemia, lymphoma, multiple myeloma, and other sites. Of the initially eligible cases, occupational information was lacking in 34% of the cases, and 38% of the controls. Analysis combined industries with Unites States census code related to justice, public order and safety which included firefighters, and for occupations combining police and fire protection services. Age- and smoking-adjusted ORs were elevated and reported as 2.1 (95% CI: 0.9–4.8, ten cases and 19 controls) for the industry of justice, public order and safety, and 2.2 (95% CI: 1.0–4.7, 12 cases and 22 controls) for police and fire protection workers. This excess risk among police and fire protection workers was confined to the astrocytic cell series (OR, 2.3; 95% CI: 1.0–5.1). The OR for firefighters examined separately was 2.0 (95% CI: 0.4–9.6), with an unknown number of cases and controls.

Carozza *et al.* (2000) conducted a population-based case–control study among adults in the San Francisco Bay area during 1991–1994. Lifetime job histories were available for this study. Using the Northern California Cancer Center population, 603 incident cases of gliomas among adults aged 20 years or older were identified with histological confirmation (ICD 9380–9481). Interviews were completed with 492 cases (82%), and 476 were analysed after additional exclusions. Using random-digit dialling, controls were frequency-matched by 5-year age groups as well as by gender and race/ethnicity. There were 754 potential controls identified with 22 removed because of their residence, insufficient level of English or some relationship to the cases. Of the 732 controls meeting the eligibility criteria, 462 (63%) interviews were completed. The job history data for cases and controls were provided by proxy for 45.6% and 0.9%, respectively. For each job reported, the following information was collected: name and location of the company, description of daily work activities, starting date and duration of job including hours worked per week. Jobs were coded using Standardized Occupational Classification 1980 and Standard Industrial Codes 1987 without knowledge of the case–control status. Duration of all jobs held for at least 6 months was analysed; the most recent 10 years were excluded to allow for a hypothesized 10-year latency period between the exposure and the clinical recognition of the disease. Subjects who were not employed in the occupational category being evaluated served as the 'unexposed' referent group. Multiple logistic analyses were used adjusting for age, gender, years of education and race (caucasian, non-caucasian). Astrocytic tumours were evaluated including glioblastoma, multiforme, and astrocytoma. The adjusted OR for 'ever' versus 'never' employed as a fireman was 2.7 (95% CI: 0.3–26.1), and for being diagnosed with having an astrocytic tumour, 3.6 (95% CI: 0.4–36, three cases, 1 control).

Table 2.4. Case–control studies of the brain

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of exposed cases	Odds Ratios (OR) (95% CI)	Adjustment for potential confounders	Comments
Brownson *et al.* (1990) Missouri, USA 1984–88	Brain and other central nervous system cancers (191 and 192)	312 caucasian males; histologically confirmed brain and central nervous system cancers, identified through the Missouri Cancer Registry, maintained by the Missouri Department of Health	1248 frequency-matched (4:1) sample of controls chosen from all other caucasian male patients diagnosed with cancers in the same time period, including lip/oral cavity/pharynx, digestive organs and peritoneum, respiratory, skin, bones and connective tissue, genitourinary, leukaemia, lymphoma, and multiple myeloma, and other sites. Controls randomly selected within each of six age strata. 38% of controls excluded due to missing occupational information	Hospital medical records	*Brain Cancer by Industry* Justice/public order/safety	10	2.1 (0.9–4.8)	Adjusted for age and smoking	Limited to caucasian males due to small numbers of non-caucasians and lack of reported occupational diversity among females. 34 % of cases excluded because of missing occupational data. Analysis combined those in police and fire protection US census codes 413–427
					Brain Cancer by occupation Police and fire protection services	12	2.2 (1.0–4.7)		
					Astrocytic cell type only	NR	2.3 (1.0–5.1)		
					Firefighters only	NR	2.0 (0.4–9.6)		

Table 2.4 (contd)

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of exposed cases	Odds Ratios (OR) (95% CI)	Adjustment for potential confounders	Comments
Carozza *et al.* (2000) San Francisco Bay area including Alameda, Contra Costa, Marin, San Mateo, San Franscisco, and Santa Clara counties, USA 1991–94	Brain (Gliomas, 9380–9481)	603 cases of histologically confirmed incident cases of glioma. Age >20 years	462 controls matched by 5-year age groups, gender, and race/ethnicity, and identified by random-digit dialling	Interviews and Standard occupational and Industrial codes used	Ever employed as firefighter	3	2.7 (0.3–26.1)	Matched on age, gender, education, and race	Only 3 cases and 1 control were firefighters. Duration of job calculated for every job held at least 6 months during subjects' lifetime also with the most recent 10 years excluded to allow for hypothesized 10-year latency period between exposure and clinical recognition of disease
					Astrocytic tumours	3	3.6 (0.4–36.1)		

Table 2.4 (contd)

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of exposed cases	Odds Ratios (OR) (95% CI)	Adjustment for potential confounders	Comments
Krishnan *et al*. (2003) Alameda, Contra Costa, Marin, San Mateo, San Francisco and Santa Clara counties, California, USA 1991–94 and 1997–99	Glioma (938.0, 948.1)	879 incident cases identified using Northern California Cancer Center's rapid ascertainment programme; 81% response rate	864 population-based controls selected by random-digit dialling; frequency- matched by age, race, and sex; 66% response rate	Interviews and Standard occupational and industrial codes used	Ever employed	9	2.85 (0.77–10.58)	Age, race and sex	40% of case participants reported by proxy Referent group for analysis included those without the given occupational group as their longest-held job, including those who were never employed
					Longest-held job as a firefighter	6	5.88 (0.70–49.01)		
					Longest-held job as a firefighter and astrocytic cases only	5	6.31 (0.73–54.40)		
					Longest held job as firefighter non-astrocytic cases	1	9.27 (0.55–155.27)		

Krishnan *et al.* (2003) conducted a follow-up study to the one designed by Carozza *et al.* (2000). This follow-up study examined incident glioma cases diagnosed during both 1991–1994 and 1997–1999. All adults newly diagnosed with glioma during these time periods were ascertained using the Northern California Cancer Center's rapid ascertainment programme. Controls were ascertained through random-digit dialling and matched to cases by age, race, and gender. There were 1129 eligible cases with 81% ($n = 896$) completing full interviews. In-person interviews were conducted for 98%, and there were 879 cases with complete information available for analysis. Of the eligible controls, 66% ($n = 864$) completed a full interview. In the analysis of 'ever' employed as a firefighter, the OR was 2.85 (95% CI: 0.77–10.58, nine cases and three controls). Analysis by the longest-held job resulted in an OR of 5.88 (95% CI: 0.70–49.01, six male cases and one male control). In the analysis of astrocytic cases, the OR was 6.31 (95% CI: 0.73–54.4, five cases and one control), and for the non-astrocytic cases, 9.27 (95% CI: 0.55–155.27, one case and one control). [These two studies are very similar with more cases and controls available in the Krishnan report. The Krishnan report, however, did not carry out analyses by 10-year latency period, and therefore both studies may be relevant.]

Bates (2007) also evaluated brain cancers (SEER code 31010) in firefighters as described above under kidney cancer and Table 2.6. There were 71 firefighters with brain cancer. The adjusted OR was 1.35 (95% CI: 1.06–1.72).

2.2.3 *Cancers of the larynx and lung*

One case–control study of cancer of the larynx and two studies of cancer of the lung were considered by the Working Group (Tables 2.5 and 2.6).

Muscat and Wynder (1995) conducted a case–control study of cancer of the larynx in New York City, USA, recorded during 1956–1965. Caucasian men from seven hospitals newly diagnosed with histologically confirmed cancer of the larynx were interviewed. Control subjects were also caucasian men frequency-matched to the cases by hospital of diagnosis, age (within 5 years), and year of interview. Eligibility as a control also required a hospital admission for a condition unrelated to an etiology associated with tobacco exposures including cancer of the prostate, lymphomas, benign prostatic hypertrophy, and various non-malignant conditions. All subjects were interviewed by personnel who were not blinded to the case–control status of subjects, with a 90% response rate. The questionnaire included information on smoking status (never, current or ex-smoker, number of cigarettes, pipe and cigars smoked, and alcohol intake). Data were collected on lifetime occupations and self-reported exposures to chemicals, metals, exhaust, asbestos, and other occupational substances. There were 235 cases and 205 controls. The cases compared to controls were most likely to be: current cigarette smokers, (66.4% and 24.4%, respectively), heavy cigarette smokers (> 31 cigarettes/day), (55.1% and 22.8%, respectively), and drink more than 7 ounces of alcohol per day (29.4% and 11.2%, respectively). Analyses were adjusted for current smoking status.

Table 2.5. Case–control studies of cancers of the larynx and lung

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of exposed cases	Odds Ratios (OR) (95% CI)	Adjustment for potential confounders	Comments
Muscat & Wynder (1995) New York, USA 1956–65	Larynx	235 caucasian men from 7 hospitals with histologically confirmed laryngeal cancer	205 caucasian men, 90% response rate of “eligible patients”; frequency-matched by hospital, age (within 5 years) and year of interview. Controls selected for condition unrelated to tobacco-induced diseases and included prostrate cancer, lymphomas, benign prostatic hypertrophy, non-malignant conditions. Only 2 firefighters (1%)	Interview				Smoking	
					Laryngeal Cancer	2			
					Classified as working in diesel exhaust job	36	0.96 (0.5–1.8)		
					Self-reporting exposure to diesel exhaust	13	1.47 (0.5–4.1)		

Table 2.5 (contd)

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of expose d cases	Odds Ratios (OR) (95% CI)	Adjustment for potential confounders	Comments
Elci *et al*. (2003) Istanbul and Marmara region, Turkey 1979–84	Lung (ICD: 162.0 and 162.2 combined, and compared to 162.3, 162,4, 162.5 and 162.9)	1354 male cases of lung cancer; 442 cases without histological confirmation	1519 male cancer and non-cancer controls diagnosed with Hodgkin disease, soft tissue sarcoma, testis, bone, male breast and non-cancer benign pathologies	Standardized questionnair eJobs classified by Standard occupational and Industrial codes	*Lung Cancer by*			Age and smoking	22 women were excluded from analyses
					Firefighter	10	6.8 (1.3–37.4)		
					Squamous cell	4	6.2 (0.8–46.2)		
					All bronchus and parenchyma	9	7.0 (1.3–39.1)		

Among the cases, two were employed as firefighters. Of those occupations which self-reported exposure to diesel exhaust, including truck drivers, firefighters, road workers, and mine workers (5.5 cases and 4.4 controls), the adjusted OR was 1.47 (95% CI: 0.5–4.1). For those occupations which self-reported exposure to diesel 'fumes', firefighter was not listed amongst them The authors noted that the self-reported exposure to diesel exhaust or diesel fumes may reflect uncontrolled confounding with cigarette smoking and alcohol consumption as almost all patients who reported diesel exposure were also heavy cigarette smokers, and consumed large amounts of alcohol.

Elci *et al.* (2003) examined the link between occupations and risk of lung cancer by histological types in Turkey. Cases were identified from an oncology treatment centre at one of the largest cancer hospitals, including treatment for workers, in Istanbul. After admission to hospital, all patients completed a standardized questionnaire administered by trained interviewers. There were 1354 male lung cancer cases with complete interview information identified during 1979–1984. An oncologist reviewed hospital records for diagnostic verification and classification of cancer types. When there were four or more cases per cancer type, histopathology and morphological type was examined. Patient controls "with the same sociodemographic background as the cases" were selected having the following diagnoses: cancers of the skin (non-melanoma), testis, bone, male breast, Hodgkin disease, soft-tissue sarcoma, and non-cancer patients. Of the 27 occupations, firefighting (n = 10 cases) had an excess risk of lung cancer, with an age- and smoking-adjusted OR of 6.8 (95% CI: 1.3–37.4). In firefighters, for squamous-cell carcinoma (n = 4), the age- and smoking-adjusted OR was 6.2 (95% CI: 0.8–46.2), and for peripheral tumours including bronchus and parenchyma (n = 9), the age- and smoking-adjusted OR was 7.0 (95% CI: 1.3–39.1).

Bates (2007) investigated cancers of the lung and bronchus in firefighters as described above under kidney cancer and in Table 2.6. There were 495 firefighters with these cancers. The adjusted OR was 0.98 (95% CI: 0.88–1.09).

2.2.4 *Cancers at other sites*

(*a*) *Multiple myeloma, non-Hodgkin lymphoma, and leukaemia*

Demers *et al.* (1993) identified cases of multiple myeloma through SEER tumour registries in four geographic locations including two counties in Washington State, two in Utah including Salt Lake City, five counties of metropolitan Atlanta, Georgia, and three metropolitan Detroit, Michigan, counties. All those potentially eligible included all incident cases diagnosed during 1977–1981. Controls were selected to be similar in age, gender, and region. In Washington State, 1683 population-based controls were selected by using two sampling units of four households. In other areas, a random-digit dialling method was used for selecting controls. Interviews were obtained from 692 (89%) of the cases or their survivors, and from 1683 (83%) of the controls.

Table 2.6. Case–control studies of other or multiple sites

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of exposed cases	Odds Ratios (OR) (95% CI)	Adjustment for potential confounders	Comments
Demers *et al.* (1993) King and Pierce counties, Washington; Davis county, Salt Lake and Weber county, Utah; Atlanta, Georgia; Detroit, Michigan; USA 1977–81	Multiple myeloma	692 cases of multiple myeloma. Total incident cases from tumour registries in the USA, aged <80 years	1683 population-based controls in Washington state selected by two sampling units of four households, and in other areas random-digit dialling; response rate 83%; matched by age, sex, and region	Interview and proxy interviews	All firefighters	5	1.9 (0.5–9.4)	Sex, race, age, and study area.	Small number of cases and controls. Uncertain as to which jobs represent firefighting and prevention occupations
					Employed ≥10 years	4	2.9 (0.4–21.6)		
					Self-responding	4	2.8 (0.5–14.3)		

Table 2.6 (contd)

Reference, study location and period	Organ site (ICD code)	Characteristics of cases	Characteristics of controls	Exposure assessment	Exposure categories	No. of exposed cases	Odds Ratios (OR) (95% CI)	Adjustment for potential confounders	Comments
Bates (2007) California, USA 1988–2003	Oesophagus Colorectum Lung Melanoma Prostate Testis Bladder Brain Thyroid Leukaemias Non-Hodgkin lymphoma Multiple myeloma	3659 cases (all men) from the California Cancer Registry, aged 21–80 years; 94% histologically confirmed	All other males in registry that were not firefighters (*n*=800448) from California Cancer Registry except those diagnosed with cancers of the lung, bronchus, prostate, colorectum, and skin melanomas.	California Cancer Registry records	Oesophagus	62	1.48 (1.14–1.91)	SES quintile	Use of other cancer controls may have biased study toward null
					Stomach	51	0.80 (0.61–1.07)		
					Colorectum	282	0.90 (0.79–1.03)		
					Caecum	52	1.09 (0.82–1.44)		
					Pancreas	63	0.90 (0.70–1.17)		
					Lung & bronchus	495	0.98 (0.88–1.09)		
					Melanoma	323	1.50 (1.33–1.70)		
					Prostate	1144	1.22 (1.12–1.33)		
					Testis	70	1.54 (1.18–2.02)		
					Bladder	174	0.85 (0.72–1.00)		
					Kidney & renal pelvis cancer	101	1.07 (0.87–1.31)		
					Brain	71	1.35 (1.06–1.72)		
					Thyroid cancer	32	1.17 (0.82–1.67)		
					Leukaemias	100	1.22 (0.99–1.49)		
					Non-Hodgkin lymphoma	159	1.07 (0.90–1.26)		
					Multiple myeloma	37	1.03 (0.75–1.43)		

SES, socioeconomic status

For the cases, 220 (32%) were interviewed by proxy. Analyses were adjusted for gender, race, 4-year age groups, and study area. The adjusted OR for employment in firefighting and prevention occupations was 1.9 (95% CI: 0.5–9.4, five cases and five controls), and for the self-reporting category, 2.8 (95% CI: 0.5–14.3, four cases). The OR for firefighters employed < 10 years was 0.9 (95% CI: 0.0–22.3, one case and two controls), while for those employed 10 or more years, the OR increased to 2.9 (95% CI: 0.4–21.6, four cases and three controls).

Bates (2007) also investigated multiple myeloma, non-Hodgkin lymphoma, and leukaemia in firefighters (for full study description see Section 2.2.1 and Table 2.6), for which the ORs were reported as 1.03 (95% CI: 0.75–1.43, 37 cases), 1.07 (95% CI: 0.90–1.26, 159 cases), and 1.22 (95% CI: 0.99–1.49, 100 cases), respectively.

(*b*) *Cancers of the gastrointestinal system and pancreas*

Bates (2007) conducted the only study investigating cancers of the gastrointestinal system in firefighters. The ORs for cancers of the stomach were 0.80 (95% CI: 0.61–1.07, 51 cases), of the colorectum 0.90 (95% CI: 0.79–1.03, 282 cases), of the caecum 1.09 (95% CI: 0.82–1.44, 52 cases), and of the pancreas 0.90 (95% CI: 0.70–1.17, 63 cases).

(*c*) *Thyroid cancer*

Bates (2007) assessed 32 firefighters with cancer of the thyroid, and found an OR of 1.17 (95% CI: 0.82–1.67).

(*d*) *Melanoma*

Bates (2007) investigated firefighters ($n = 323$) diagnosed with melanoma, and found a significant and elevated OR of 1.50 (95% CI: 1.33–1.70).

2.3 Descriptive studies

Several descriptive studies have provided results for firefighters. These have varied in their design including cohort studies based on record linkage, and studies based solely on death certificate or registry data. In some cases, these have been investigations specifically directed at firefighters. They are described in more detail below and in Tables 2.7 and 2.8.

2.3.1 *Cohort and linkage studies of firefighters*

Feuer & Rosenman (1986) conducted a study of deaths among active and retired firefighters from the state of New Jersey, USA, during 1974–1980. Firefighters were identified using pension records, and their duration of employment was also collected. Their mortality was compared to that of the police force, identified in the same manner, and of the general population. Proportionate mortality ratios (PMRs) were calculated based on 263 caucasian male firefighter deaths, and a significant excess of leukaemia was observed using to the police force as reference group.

Table 2.7. Cohort and linkage studies of firefighters

Reference, location, name of study	Study population description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	PMR/SMR/MOR (95% CI)	Adjustement for potential confounders	Comments
Feuer & Rosenman (1986), New Jersey, USA 1974–80	263 active and retired firefighters, identified using retirement system records	Pension records				**PMR**	Age	
			All cancers	Overall, compared to NJ	67	1.0 [n.s.]		
				≤20 years	15	0.9 [n.s.]		
				20–25 years	18	1.0 [n.s.]		
				>25 years	34	1.1 [n.s.]		
				Compared to Police	67	1.1 [n.s.]		
			Digestive	Overall, compared to NJ	20	1.1 [n.s.]		
				≤ 20 years	5	1.2 [n.s.]		
				20–25 years	5	1.0 [n.s.]		
				>25 years	10	1.2 [n.s.]		
				Compared to Police	20	0.9 [n.s.]		
			Respiratory	Overall, compared to NJ	23	0.9 [n.s.]		
				≤ 20 years	4	0.7 [n.s.]		
				20–25 years	7	1.0 [n.s.]		
				>25 years	12	1.0 [n.s.]		
				Compared to Police	23	1.0 [n.s.]		
			Skin	Overall, compared to NJ	4	1.9 [n.s]		
				≤ 20 years	0	0.0 [n.s.]		
				20–25 years	1	1.8 [n.s.]		
				>25 years	3	3.9 [n.s.]		
				Compared to Police	4	1.4 [n.s.]		
			Leukaemia	Compared to NJ	4	1.8 [n.s.]		
				Compared to Police	4	2.8 [$P<0.05$]		

Table 2.7 (contd)

Reference, location, name of study	Study population description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	PMR/SMR/MOR (95% CI)	Adjustement for potential confounders	Comments
Hansen (1990), Denmark	Mortality among 886 men identified as firefighters in the 1970 census followed through 1980 compared to men in similar occupations	Occupation as reported in the Census		Males		**SMR**	Age, calendar period	
			All	Overall	21	1.2 (0.7–1.8)		
				Age 30–49	NR	4.4 (1.4–10.2)		
				Age 50–59	NR	1.0 (0.3–2.3)		
				Age 60–74	NR	1.9 (0.9–3.7)		
			Lung	Overall	9	1.6 (0.8–3.1)		
				Age 30–49	NR	0.0 (0.0–1.5)		
				Age 50–59	NR	1.4 (0.2–4.9)		
				Age 60–74	NR	3.2 (1.2–6.9)		

Table 2.7 (contd)

Reference, location, name of study	Study population description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	PMR/SMR/MOR (95% CI)	Adjustement for potential confounders	Comments
Ma *et al.* (1998), 24 states, USA	Analysis of 1984–1993 death certificate data, 6607 firefighters identified	Usual occupation on death certificate		Overall, caucasian males		**MOR**	Age, year of death	
			All		1817	1.1 (1.1–1.2)		
			Lip		3	5.9 (1.9–18.3)		
			Colon		149	1.0 (0.9–1.2)		
			Rectum		27	1.1 (0.8–1.6)		
			Pancreas		88	1.2 (1.0–1.5)		
			Lung		633	1.1 (1.0–1.2)		
			Prostate		189	1.2 (1.0–1.3)		
			Bladder		48	1.2 (0.9–1.6)		
			Kidney & pelvis		49	1.3 (1.0–1.7)		
			Brain & CNS		41	1.0 (0.8–1.4)		
			non-Hodgkin lymphoma		76	1.4 (1.1–1.7)		
			Multiple Myeloma		28	1.1 (0.8–1.6)		
			Leukaemia		60	1.1 (0.8–1.4)		
			Soft tissue sarcoma		14	1.6 (1.0–2.7)		
				Overall, black males				
			All		66	1.2 (0.9–1.5)		
			Nasopharynx		1	7.6 (1.3–46.4)		
			Colon		9	2.1 (1.1–4.0)		
			Pancreas		5	2.0 (0.9–4.6)		
			Lung		15	0.8 (0.5–1.3)		
			Prostate		16	1.9 (1.2–3.2)		
			Brain & CNS		5	6.9 (3.0–16.0)		

* specify *P* value if no confidence interval indicated; MOR, mortality odds ratio; NJ, New Jersey; NR, not reported; n.s, not significant; PMR, proportionate mortality ratio; SMR, standardized mortality ratio

Hansen (1990) performed a study of Danish firefighters employed at the time of the 1970 national census. An analysis was then conducted of 57 deaths (21 from cancer) during 1970–1980 occurring among 886 males who had reported employment as firefighter. Men employed in similar occupations were used as the reference group, and an excess of lung cancer among firefighters over the age of 60 was reported, based on small numbers.

Ma *et al.* (1998) conducted a further analysis of a data set collected by Burnett *et al.* (1994) with additional years of follow-up using 1984–1993 death certificate data from 24 states in the USA. A total of 6607 deaths and 1883 cancer deaths among firefighters were identified based on the occupational titles on death certificates. Race-specific cancer mortality odds ratios (MORs) were calculated with all non-cancer deaths as the reference group. Analyses were adjusted for age and year of death. Among caucasian male firefighters, significant excesses were observed for cancers of the lip, pancreas, lung, prostate, kidney, and soft-tissue sarcoma and non-Hodgkin lymphoma. Among black male firefighters, significant excesses were observed for cancers of the nasopharynx, colon, prostate, and brain.

2.3.2 *Descriptive studies with firefighter results.*

There is a large body of descriptive epidemiology carried out for the purpose of occupational cancer and mortality surveillance. The results of these studies are summarized in Table 2.8.

Berg & Howell (1975) examined the risk of colorectal cancer by occupation using death certificate data from the USA and the United Kingdom and observed an excess among firefighters. [The Working Group noted that there was an overlap between the United Kingdom data included in this study and the meta-analysis by Dubrow & Wegman, 1983].

Williams *et al.* (1977) observed excesses of oral cancer, lung cancer, bladder cancer, and non-Hodgkin lymphoma based on the small number of cancers among firefighters that were included in the Third National Cancer Survey, USA. [The Working Group noted that Williams *et al.* (1977) was included in the meta-analysis conducted by Dubrow & Wegman (1983), but was unique in that occupation was ascertained by interview.]

Dubrow & Wegman (1983) summarized the results of ten early USA and United Kingdom studies and reported the results that appeared to be most consistent between the studies. Among those studies that reported results for firefighters, large intestine cancer and multiple myeloma were significantly elevated.

Morton & Marjanovic (1984) examined the incidence of leukaemia by occupation in the Portland–Vancouver metropolitan area in North-western USA, and excesses were observed among firefighters based on very small numbers.

Mortality among a cohort of 293 958 United States military veterans was examined by occupation and industry (Blair *et al.,* 1985). Usual occupation and industry as well as smoking information was determined from questionnaires completed in 1954 and 1957, and 107 563 deaths were recorded during 1954–1970. Excesses of rectal, bladder, and brain cancers were observed based on very small numbers.

Gallagher *et al.* (1989) conducted a study of mortality by occupation and industry using death certificate data during 1950–1984 from the Canadian province of British Columbia. There were 1202 deaths among firefighters identified based on occupational titles on death certificates. PMRs were calculated with adjustment for 5-year age and calendar period. There were 197 cancer deaths, and a small excess of overall cancer as well as a significant excess of pancreatic cancer was observed.

In the USA, Sama *et al.* (1990) examined cancer incidence among firefighters using the Massachusetts Cancer Registry records for 1982–1986. Employment as a firefighter was based on the usual occupation reported to the Registry. The analysis was restricted to 315 Caucasian male firefighters. Case–control analyses were conducted for nine different cancer types and two 'unexposed' reference populations were used: policemen and statewide males. Standardized morbidity odds ratios (SMORs) were calculated and significant excesses of malignant melanoma and bladder cancer were observed compared to the general population. Excesses of bladder cancer and non-Hodgkin lymphoma were observed when compared to policemen.

An analysis of deaths in England and Wales (1979–1980 and 1982–1990) were examined by occupation (OPCS, 1995). A total of 2968 deaths among male firefighters and 16 deaths among their female counterparts were observed based on the last occupation listed on death certificates. Only statistically significant results were reported, and excesses of oesophageal, stomach, and gall bladder cancer mortality were observed among men.

A follow-up study was conducted in the Finnish working-age population identified in the 1970 census (Pukkala, 1995). A total of 1436 male firefighters were identified during the follow-up period during 1971–1985 through linkage with the Finnish tumour registry. No statistically significant excesses were observed. The largest excess reported was for non-localized prostate cancer.

In Canada, Finkelstein (1995) examined occupations associated with lung cancer using a case–control study based on death certificates in two Ontario cities, and observed an excess among firefighters based on small numbers.

Milham (1997) conducted a study of mortality by occupation and industry using death certificate data (1950–1989) from the state of Washington, USA. A total of 2266 deaths among firefighters were identified based on the occupational titles on death certificates. PMRs were calculated and adjusted by 5-year age group and calendar period. There were 197 cancer deaths and a small excess of overall cancer was observed as well as significant excesses of melanoma and lympho- and reticulosarcoma. [The Working Group noted that there was an overlap between this and the multistate studies conducted by NIOSH, but that this had the longest follow-up period and was the earliest study of its kind in North America.]

Table 2.8. Descriptive studies with results on firefighters

Reference, location, name of study	Study population description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	RR/SIR/SMR (95% CI)*	Adjustement for potential confounders	Comments
Berg & Howell (1975), USA & UK	US males aged 20–44, who died in 1950, and UK male deaths, 1949–1953 and 1959–1963	Occupation on death certificate	Colorectum	Overall	39	**PMR** 1.72 **SMR** 2.79	Age, calendar period	Overlap with Dubrow & Wegman, (1983)
Williams *et al.* (1977), USA	34 male firefighters with incident cancer included in the Third National Cancer Survey, 1969–1971	Occupation from interview				**OR**	Age, race, education, smoking, alcohol	Overlap with Dubrow & Wegman, (1983)
			Oral cavity	Overall, male	4	2.44 [n.s.]		
			Colon		4	0.80 [n.s.]		
			Lung		8	1.78 [n.s.]		
			Prostate		5	0.90 [n.s.]		
			Bladder		4	2.72 [n.s.]		
			Lymphosarcoma		2	15.30 [n.s.]		
			Other, non-Hodgkin lymphoma		1	3.39 [n.s.]		

Table 2.8 (contd)

Reference, location, name of study	Study population description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	RR/SIR/SMR (95% CI)*	Adjustement for potential confounders	Comments
Dubrow & Wegman (1983), USA & UK	Meta analysis of 10 surveillance studies	Varied	Large intestine (excl. rectum)	Overall, summary result from 5 studies reporting	70	**Summary RR** 1.3 ($P<0.05$)	Age, at least	Studies included in the meta-analysis Milham (1976), Petersen & Milham (1980), OPCS (1978), Guralnick (1963), Williams *et al.* (1977), Decoufle *et al.* (1977), Gute (1981), OPCS (1971, 1972,1975), Dubrow & Wegman (1984)
			Multiple myeloma	Overall, summary result from 3 studies reporting	11	2.0 ($P<0.05$)		
Morton & Marjanovic (1984), Portland–Vancouver, USA	1678 leukaemia cases aged 16–67 from the records of 24 hospitals and death certificates, 1963–1977	Occupation abstracted from hospital records and death certificates		Firefighters		**SIR**	Age	1970 Census data used for reference
			Leukaemia	Overall leukaemia	4	3.5 ($P<0.01$)		
			Lymphatic	Lymphatic	1	2.1 [n.s.]		
			Non-lymphatic	Non-lymphatic	3	4.5 ($P<0.01$)		

Table 2.8 (contd)

Reference, location, name of study	Study population description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	RR/SIR/SMR (95% CI)*	Adjustement for potential confounders	Comments
Blair *et al.*, (1985); Walrath *et al.* (1985); USA	Follow–up (1954–1970) of 902 USA Veterans reporting occupation as firefighter	Usual occupation from interview		Overall, Male		**SMR**	Age, calendar period, smoking	
			Intestine		8	1.4 [n.s.]		
			Lung, bronchus		13	1.1 [n.s.]		
Gallagher *et al.* (1989), British Columbia, Canada	Death certificate study 1950–1984. 1202 firefighter deaths	Usual occupation on death certificate				**PMR**	Age, calendar period	
			All		197	1.2 (1.0–1.3)		
			Colon		20	1.4 (0.8–2.1)		
			Rectum		10	1.2 (0.6–2.2)		
			Pancreas		19	1.7 (1.1–2.7)		
			Lung		50	1.0 (0.8–1.4)		
			Prostate		23	1.4 (0.9–2.1)		
			Bladder		9	1.5 (0.7–2.9)		
			Kidney		3	0.7 (0.1–2.1)		
			Brain		6	1.2 (0.4–2.7)		
			Non-Hodgkin lymphoma		7	1.5 (0.6–3.2)		
			Multiple myeloma		2	0.8 (0.1–2.9)		
			Leukaemia		8	1.3 (0.5–2.5)		

Table 2.8 (contd)

Reference, location, name of study	Study population description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	RR/SIR/SMR (95% CI)*	Adjustement for potential confounders	Comments
Hrubec *et al.* (1992) USA	Follow-up 1954–80 of 902 USA veterans reporting occupation as a firefighter	Usual occupation on death certificate		Occupation as a firefighter		**RR (90% CI)**	Age, calendar period	
			All cancer		110	1.2 (1.1–1.4)		
			Rectum		7	2.2 (1.2–4.2)		
			Prostate		12	1.1 (0.7–1.7)		
			Bladder		8	2.1 (1.2–3.8)		
			Brain		5	2.3 (1.1–4.9)		
			Malignant lymphoma		2	0.4 (NR)		
			Leukaemia		3	0.7 (NR)		

Table 2.8 (contd)

Reference, location, name of study	Study population description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	RR/SIR/SMR (95% CI)*	Adjustement for potential confounders	Comments
Sama *et al.* (1990) Massachusetts, USA	315 cases of cancer identified from the Massachusettes Tumor Registry between 1982–86 Two reference groups of unexposed cases; state population and police; aged 18 and older at the time of diagnosis	Usual occupation from tumour registry records		Caucasian males		**SMOR**	Age, smoking race	
			Colon	Overall, compared to state population	33	1.2 (0.8–1.8)		
				Overall, compared to Police	33	1.0 (0.6–1.8)		
			Rectum	Overall, compared to state population	22	1.4 (0.8–2.2)		
				Overall, compared to Police	22	1.0 (0.5–1.9)		
			Pancreas	Overall, compared to state population	6	1.0 (0.4–2.3)		
				Overall, compared to Police	6	3.2 (0.7–14.2)		
			Lung	Overall, compared to state population	71	1.2 (0.9–1.7)		
				Overall, compared to Police	71	1.3 (0.8–2.0)		
			Melanoma	Overall, compared to state population	26	2.9 (1.7–5.0)		
				Overall, compared to Police	18	1.4 (0.6–3.2)		
			Bladder	Overall, compared to state population	26	1.6 (1.0–2.5)		
				Overall, compared to Police	26	2.1 (1.1–4.1)		
			Brain & other nervous system	Overall, compared to state population	5	0.9 (0.3–2.2)		
				Overall, compared to Police	5	1.5 (0.4–5.9)		

Table 2.8 (contd)

Reference, location, name of study	Study population description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	RR/SIR/SMR (95% CI)*	Adjustement for potential confounders	Comments
Sama *et al.* (1990) (contd)			Non-Hodgkin lymphoma	Overall, compared to state population	14	1.6 (0.9–2.8)		
				Overall, compared to Police	14	3.3 (1.2–9.0)		
			Leukaemia	Overall, compared to state population	6	1.1 (0.5–2.6)		
				Overall, compared to Police	6	2.7 (0.6–11.5)		
OPCS (1995), England and Wales UK	Death certificate study 1979–1980, 1982–1990. 2698 deaths among men and 16 deaths among women	Last occupation on death certificate				**PMR**	Age	Only statistically significant results reported
			All cancers	Men	432	1.16		
			Oesophagus		46	1.4 (1.0–1.8)		
			Stomach		91	1.5 (1.2–1.8)		
			Gallbladder		10	2.2 (1.1–4.1)		
			All cancers	Women	2	1.07		
Finkelstein (1995), Ontario, Canada	Population-based case–control study using death certificate data between 1979–1988 Males age 45–75 years	Usual occupation on death certificate		Male firefighters		**RR**	Age, year of death, city of residence	
			Lung		6	1.9 (0.6–6.3)		

Table 2.8 (contd)

Reference, location, name of study	Study population description	Exposure assessment	Organ site (ICD code)	Exposure categories	No. of cases/ deaths	RR/SIR/SMR (95% CI)*	Adjustement for potential confounders	Comments
Milham (1997), Washington State, USA	Death certificate study 1950–1989. 2266 firefighter deaths	Usual occupation on death certificate				**PMR**	Age, Calendar period	
			All Cancers		476	1.1 (1.0–1.2)		
			Buccal cavity & pharynx		7	0.6 (0.3–1.3)		
			Oesophagus		11	1.1 (0.6–2.0)		
			Stomach		22	0.8 (0.5–1.2)		
			Colon		36	0.9 (0.6–1.2)		
			Rectum		15	1.1 (0.6–1.8)		
			Pancreas		28	1.1 (0.7–1.6)		
			Larynx		3	0.6 (0.1–1.8)		
			Lung		120	1.0 (0.8–1.2)		
			Prostate		56	1.1 (0.8–1.5)		
			Kidney		9	0.9 (0.4–1.6)		
			Bladder & urinary		23	1.4 (0.9–2.1)		
			Melanoma		9	2.1 (1.0–4.1)		
			Brain & nervous system		19	1.6 (0.9–2.4)		
			Lympho- & reticulosarcoma		13	1.8 (1.0–3.0)		
			Hodgkin lymphoma		7	1.8 (0.7–3.7)		
			Other lymphoma		3	0.5 (0.1–1.4)		
			Multiple myeloma		9	1.3 (0.6–2.4)		
			Leukaemia		27	1.4 (0.9–2.1)		

* specify *P*–value if no confidence interval indicated
NR, not reported; n.s, not significant

2.4 Case reports

Individual firefighters have applied for, and sometimes received, workers' compensation for cancer. An apparent cluster of cancer among firefighters was reported in an investigation of a chemical waste dump fire by NIOSH (Hrubec *et al.,* 1992). However, the authors concluded it was not likely to have been related to firefighting. [Given the limitations of these reports and the large number of descriptive, cohort, and case–control studies with data on firefighters, the Working Group did not believe that case reports would contribute to the evaluation.]

2.5 Meta-analyses

Two meta-analyses of studies of firefighters and cancer have been conducted (Howe & Burch, 1990; LeMasters *et al.,* 2006). The most recent meta-analysis included a great majority of the studies considered by the Working Group (LeMasters *et al.,* 2006). Cancer risk was significantly elevated for ten of the 21 cancer types analysed (stomach, colon, rectum, skin, prostate, testis, brain, non-Hodgkin lymphoma, multiple myeloma, and malignant melanoma). With the exception of testicular cancer (summary RR = 2.02), the summary relative risk estimates were moderate, ranging from 1.21 for colon to 1.53 for multiple myeloma. For four of these sites (prostate, testis, non-Hodgkin lymphoma, and multiple myeloma), findings were consistent across study designs and the types of study available. However, since that analysis, two additional large studies of cancer in firefighters had been published (Ma *et al.,* 2006; Bates, 2007). Therefore, another meta-analysis was performed by the Working Group to assess the impact of these recent studies.

Inclusion criteria for studies in this meta-analysis were reported estimates of relative risk with corresponding 95% confidence intervals or information that allowed their computation by the Working Group for 'ever' versus 'never' exposure to firefighting or employment as a firefighter. For those studies that did not report for this category, the relative risks and 95% confidence intervals were estimated by the Working Group from strata-specific relative risk and corresponding number of cases, assuming a normal distribution when possible. Studies that only reported point estimates without confidence intervals were not included. Proportionate mortality studies were also excluded. Statistical heterogeneity among studies was tested with the Q statistic. Summary relative risk estimates were obtained from random-effect models for prostate cancer (Q = 32.816, $P = 0.005$), and fixed-effect models for testicular cancer (Q = 3.928, $P = 0.560$), and non-Hodgkin lymphoma (Q = 6.469, $P = 0.486$). All statistical analyses were performed using STATA (version 9.0; StataCorp, College Station, TX).

Based on the Working Group's meta-analysis, three of the four sites remained statistically significant. Testicular cancer was evaluated based on six studies and

409 cases (Giles *et al.,* 1993; Aronson *et al.,* 1994; Bates *et al.,* 2001; Stang *et al.,* 2003; Ma *et al.,* 2006; and Bates, 2007). The results demonstrated an approximate 50% increased risk (1.47, 95% CI: 1.20–1.80, fixed effects). Prostate cancer was evaluated using 16 available studies and 1764 cases (Aronson *et al.,* 1994; Baris *et al.,* 2001; Bates *et al.,* 2001 ; Bates, 2007; Beaumont *et al.,* 1991; Demers *et al.,* 1994; Firth *et al.,* 1996; Giles *et al.,* 1993; Grimes *et al.,* 1991; Guidotti 1993; Krstev *et al.,* 1998; Ma *et al.,* 1998; Ma *et al.,* 2006; Pukkala, 1995; Tornling *et al.,* 1994; and Vena & Fiedler, 1987). The results showed a 30% elevated risk (1.30; 95% CI: 1.12–1.51, random effects). Non-Hodgkin lymphoma was evaluated based on seven studies and 312 cases, and had a 21% elevated risk estimate (1.21; 95% CI: 1.08–1.36, fixed effects) (Baris *et al.,* 2001; Bates, 2007; Giles *et al.,* 1993; Ma *et al.,* 1998, 2006; Pukkala, 1995; and Sama *et al.,* 1990).

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