

Cancer Incidence Among Male Massachusetts Firefighters, 1987–2003

Dongmug Kang, MD, PhD,¹ Letitia K. Davis, ScD,^{2*}
Phillip Hunt, PhD,² and David Kriebel, ScD³

Background Firefighters are known to be exposed to recognized or probable carcinogens. Previous studies have found elevated risks of several types of cancers in firefighters.

Methods Standardized morbidity odds ratio (SMORs) were used to evaluate the cancer risk in white, male firefighters compared to police and all other occupations in the Massachusetts Cancer Registry from 1986 to 2003. Firefighters and police were identified by text search of the usual occupation field. All other occupations included cases with identifiable usual occupations not police or firefighter. Control cancers were those not associated with firefighters in previous studies.

Results Risks were moderately elevated among firefighters for colon cancer (SMOR = 1.36, 95% CI: 1.04–1.79), and brain cancer (SMOR = 1.90, 95% CI: 1.10–3.26). Weaker evidence of increased risk was observed for bladder cancer (SMOR = 1.22, 95% CI: 0.89–1.69), kidney cancer (SMOR = 1.34, 95% CI: 0.90–2.01), and Hodgkin's lymphoma (SMOR = 1.81, 95% CI: 0.72–4.53).

Conclusions These findings are compatible with previous reports, adding to the evidence that firefighters are at increased risk of a number of types of cancer. *Am. J. Ind. Med.* 51:329–335, 2008. © 2008 Wiley-Liss, Inc.

KEY WORDS: firefighter; cancer; SMOR; police; surveillance

INTRODUCTION

Firefighters are known to be exposed to recognized or probable carcinogens. These include benzene, polycyclic aromatic hydrocarbons, benzo(a)pyrene, formaldehyde, chlorophenols, dioxins, ethylene oxide, orthotoluidine, polychlorinated

biphenyls, vinyl chloride, methylene chloride, trichloroethylene, diesel fumes, arsenic, and asbestos [Bendix, 1979; Treitman et al., 1980; Fitzgerald et al., 1986; Froines et al., 1987; Brand-Rauf et al., 1988, 1989; Jankovic et al., 1992; Burgess and Crutchfield, 1995; Moen and Ovrebo, 2001; Austin et al., 2001a,b; Caux et al., 2002].

In the past several decades, a number of studies on the relationship between firefighters and cancer have been conducted [Brownson et al., 1987; Vena and Fiedler, 1987; Heyer et al., 1990; Sama et al., 1990; Demers et al., 1992; Guidotti, 1993; Aronson et al., 1994; Burnett et al., 1994; Tornling et al., 1994; Guidotti, 1995; Baris et al., 2001]. After review of the studies, several authors [Golden et al., 1995; Bogucki and Rabinowitz, 2005] suggested that leukemia, non-Hodgkin's lymphoma, multiple myeloma, brain and bladder cancer have strong evidence, and rectal, colon, stomach, prostate cancer, and melanoma have weaker but plausible evidence of association with firefighting. However, there remain important inconsistencies in the strength of

¹Department of Preventive and Occupational Medicine, Pusan National University School of Medicine, Busan, Korea

²Occupational Health Surveillance Program, Massachusetts Department of Public Health, Boston, Massachusetts

³Department of Work Environment, University of Lowell, Lowell, Massachusetts
Contract grant sponsor: National Institute for Occupational Safety and Health, Cooperative Agreement; Contract grant number: U60/OH008490.

*Correspondence to: Dr. Letitia K. Davis, Occupational Health Surveillance Program, Massachusetts Department of Public Health, 250 Washington Street, Boston, MA 02108.
E-mail: letitia.davis@state.ma.us

Accepted 31 October 2007
DOI 10.1002/ajim.20549. Published online in Wiley InterScience
(www.interscience.wiley.com)

evidence reported by other authors. Guidotti [1995] concluded that lung, colon, rectum, and genitourinary tract cancers including kidney, ureter, and bladder, have strong evidence, while brain cancer has inadequate evidence of an association with firefighters. Haas et al. [2003] reviewed all cancers combined, lung cancer and brain cancer, and reported that only the standardized mortality ratio of brain cancer was consistently higher in firefighters. Other recent studies show the association of firefighting with other types of cancer including laryngeal [Muscat and Wynder, 1995], lip, nasopharynx, pancreas, soft tissue sarcoma, and Hodgkin's disease [Ma et al., 1998], testicular [Bates et al., 2001; Stang et al., 2003], male breast cancer, and thyroid cancer [Ma et al., 2005]. Hence there continues to be a need for additional studies on the relationships between cancers and firefighting.

Cancer patterns among firefighters in Massachusetts were reported previously for the period 1982–1986 [Sama et al., 1990]. We used the same dataset, the Massachusetts Cancer Registry, to study cancer among firefighters for a considerably longer period—the 17 years from 1987 to 2003. We have also studied a wider range of cancer sites than Sama and colleagues.

MATERIALS AND METHODS

Exposed and Unexposed Groups

Subjects were white male cancer cases in the Massachusetts Cancer Registry newly diagnosed in 1987 through 2003 by all Massachusetts acute care hospitals and one medical practice association. (Additional physicians' offices and pathology laboratories began reporting in 2001; Radiation Therapy Centers in 2002.) Non-Massachusetts residents and those aged under 18 years at the time of diagnosis were excluded. There were too few female firefighters to permit analyses of cancer incidence.

Usual occupation and industry, defined as the longest job held, were used to define exposure groups. These data are gathered by cancer registrars in each hospital, and are entered into the Registry as narrative text. Cases for which no usual occupation was specified were excluded. "Firefighters" were identified by searching the usual occupation text field for the strings: "firema(e)n," "firefighter," "fire lieutenant," "fire chief" or "fire captain." To eliminate people who worked for fire departments but were not involved directly in firefighting, "fire inspector," "investigator," and "dispatcher" were excluded. Also, workers who are called "fireman" in other industries, such as foundry workers, stationary fireman, and boiler fireman, were excluded. Volunteer firefighters were also excluded. Two comparison groups were used: police and all Cancer Registry cases for whom any occupational information was reported (other than firefighter or police). Police were defined by searching usual occupation for text strings including: "policeman," "police chief," "sheriff," "correc-

tional officer," "prison guard (officer)," "security," "police detective," "police security," "marshal," "law enforcement," "constable," "FBI," "police investigator," "court guard (officer)," "probation," "deputy," "prison warden," and "jail guard (officer)." People who were employed in a police department but had another job title such as maintenance, electrician etc., and police belonging to private organizations (campus, college, private guard) were not included. Cases whose usual occupation information listed both police and firefighter were classified as firefighters. Because of extremely small numbers, cases and comparison subjects with race African American (3.1%), "Other" (1.1%) and "unknown" race (1.8%) were excluded.

Cancers of Concern

We identified all cancers for which evidence of an association with firefighting has been reported. We performed a PubMed search for the years 1966–2006, using key words "firefighter" and "fireman," cross-referenced with "cancer." After the web search and assembling articles, the reference sections of the articles were reviewed. Included in our list of cancers of concern was any site for which at least two studies reported observing a relationship with firefighting. Twenty-five cancers were regarded as cancers of concern. Each cancer and its ICD-O-3 codes are follows: Lip (0–9), Buccal cavity (30–69), Nasopharynx (110–113, 118–119), Pharynx (140–142, 148), Esophagus (150–159), Stomach (160–169), Colon (180, 182–189, 199), Rectum (209), Liver (220–221), Pancreas (250–259), Larynx (320–329), Lung (340–349), Skin melanoma (ICD-O-3 440–449 and histology type 8,720–8,780), Soft tissue sarcoma (470–479, 490–499), Breast (500–509), Prostate (619), Testicle (620–629), Kidney (649), Bladder (670–679), Brain (710–719), Thyroid (739), Leukemia (histology type 9,800–9,948), Non-Hodgkin's Lymphoma (histology type 9,590–9,596, 9,670–9,596, 9,727–9,729, 9,827), Hodgkin's lymphoma (histology type 9,650–9,667), Multiple Myeloma (histology type 9,731–9,732).

Confounders

Hospital registrars record age, gender, and smoking status, along with detailed information on the tumor, histology, staging, etc. After January 1, 1996, current cigarette, cigar/pipe, and smokeless tobacco users were differentiated in the MCR. Current, ex-, and never tobacco use of any kind are used in the analysis. Age and smoking were studied as potential confounders in these analyses.

Analysis

Because of numerator-only data of this study, the standardized morbidity odds ratio (SMOR) was used to

measure associations between firefighting and specific cancer types. The SMOR expresses the ratio of the odds of having the cancer of interest among firefighters to the odds among the unexposed group (either police or all known occupations). It can also be thought of as the ratio of the number of cases of cancer observed among firefighters to the number expected, were the firefighters to experience the same cancer risk as the comparison population. The method requires not only an "unexposed" group, but also a comparison set of cancer sites not identified as cancers of concern as described above [Checkoway et al., 2004]. The SMOR is less biased than the Proportional Mortality Ratio (PMR), which is an alternative method often used when denominator data are not available [Miettinen and Wang, 1981; Park et al., 1992]. SMORs were calculated using logistic regression, permitting control for confounders of age and smoking status [Smith and Kliewer, 1995]. Each cancer site was compared individually to the comparison cancers with each of the two unexposed referent groups. Associations were also calculated in three age strata: 18–54, 55–74 and 75+, the same groupings used in the previous report [Sama et al., 1990]. Analyses were performed using SAS v. 9.1.

RESULTS

Among the 258,964 eligible cancer cases (white male residents of Massachusetts equal or older than 18 years of age, registered in Massachusetts in the 17 year period from 1987 to 2003), 161,778 (62.5%) had a usual occupation listed, of which 2,125 were firefighters (1.3%). The distribution of firefighters, police, and other occupations, by age at diagnosis, smoking status, and specific cancer type are presented in Table I.

SMORs for the cancers of concern are shown in Table II, using both unexposed groups, after adjusting age and smoking status. Results with the two different unexposed groups were fairly similar, which gives confidence that there was no important bias from the choice of one or the other. One notable discrepancy was the results for melanoma; compared to police, there was a reduced risk among firefighters (SMOR = 0.65, 95% CI: 0.44–0.97), while the firefighters and the all occupations comparison group had quite similar risks (SMOR = 1.04, 95% CI: 0.77–1.42).

For clarity, we focus further presentation of results on the police comparison group. There were moderate elevations in risk for colon cancer (SMOR = 1.36, 95% CI: 1.04–1.79), and brain cancer (SMOR = 1.90, 95% CI: 1.10–3.26). Weaker evidence of increased risk among firefighters was also observed for bladder cancer (SMOR = 1.22, 95% CI: 0.89–1.69), kidney cancer (SMOR = 1.34, 95% CI: 0.90–2.01), and Hodgkin's lymphoma (SMOR = 1.81, 95% CI: 0.72–4.53).

Age stratified SMORs provided some additional insights into the elevated risks described above (Table III). The

TABLE I. Distribution of Cancer Cases by Age, Smoking Status, and Cancer Site Among Firefighters, Police, and Other Occupations in Massachusetts, 1987–2003

	Firefighters		Police		Other occupations	
	n	%	n	%	n	%
Age*						
<55	330	15.5	531	19.2	30,663	19.5
55–75	1,257	59.2	1,633	59.1	87,429	55.7
75+	538	25.3	599	21.7	38,798	24.7
Smoking status ^a						
Non-smoker	500	27.9	625	26.5	38,734	30.1
Past smoker	834	46.5	1,063	45.1	53,011	41.1
Current smoker	461	25.7	671	28.4	37,148	28.8
Missing	330		404		27,997	
Total	2,125	100.0	2,763	100.0	156,890	100.0

Massachusetts Cancer Registry.

* $P < 0.05$.

^aCases with unknown smoking status are not included in percent distribution.

elevated colon cancer risk occurred only among the 75+ age group (SMOR = 1.73, 95% CI: 1.06–2.84), while brain cancer risk appeared elevated across all age groups, with wide confidence intervals because of the smaller numbers in each stratum. Bladder cancer was only moderately elevated in each age group with no clear pattern. Hodgkin's lymphoma risk was highest in the youngest age stratum, but with wide confidence interval. The pattern of risks for melanoma across age strata again showed divergent results depending upon which unexposed referent group was used. Using the police referent, the firefighters appeared to have lower risk across all age groups, but particularly in the oldest group (SMOR = 0.35, 95% CI: 0.13–0.91). In contrast, the firefighters had *higher* risk than the all occupations reference group, in the youngest age stratum (SMOR = 1.82, 95% CI: 1.09–3.04) (data not shown).

DISCUSSION

Strengths and Limitations of Registry-Based Occupational Cancer Studies

Registry-based studies of occupational risks have many well-recognized limitations [Checkoway et al., 2004]. One limitation is the underreporting of occupational information, which was available for approximately 62.5% of all cases in the period under study. Thus there were quite likely other cases of cancer among firefighters and police of which we are not aware. This numerator-based analysis method (the total number of firefighters from which the cases came cannot be determined) would produce biased risk estimates if the

TABLE II. Cancer Risk Among Massachusetts Firefighters, 1987–2003

Cancer type ^a	No.	%	Reference group					
			Police			All other occupations		
			SMOR	95% CI		SMOR	95% CI	
Lip	4	0.2	1.10	0.24	5.06	1.05	0.33	3.30
Buccal cavity	21	1.0	0.72	0.37	1.41	0.66	0.41	1.06
Nasopharynx	3	0.1	1.17	0.19	7.17	1.31	0.32	5.31
Esophagus	57	2.7	0.93	0.61	1.41	0.64	0.47	0.87
Stomach	46	2.2	0.83	0.53	1.29	0.97	0.69	1.35
Colon	200	9.4	1.36	1.04	1.79	1.15	0.93	1.43
Rectum	67	3.2	0.86	0.58	1.26	1.03	0.77	1.38
Liver	19	0.9	1.15	0.55	2.41	1.19	0.69	2.06
Pancreas	38	1.8	0.86	0.53	1.40	0.84	0.58	1.22
Larynx	38	1.8	0.66	0.39	1.10	0.81	0.57	1.16
Lung	379	17.8	1.02	0.79	1.31	0.91	0.76	1.10
Skin melanoma	78	3.7	0.65	0.44	0.97	1.04	0.77	1.42
Soft tissue sarcoma	14	0.7	1.05	0.46	2.37	1.06	0.59	1.91
Breast	4	0.2	0.25	0.03	2.31	1.28	0.47	3.47
Prostate	577	27.2	0.98	0.78	1.23	1.05	0.88	1.24
Testicular	25	1.2	1.53	0.75	3.14	1.48	0.88	2.48
Kidney	64	3.0	1.34	0.90	2.01	1.01	0.74	1.38
Bladder	113	5.3	1.22	0.89	1.69	1.19	0.93	1.52
Brain	28	1.3	1.90	1.10	3.26	1.36	0.87	2.12
Thyroid	10	0.5	0.71	0.30	1.70	0.81	0.41	1.59
Leukemia	46	2.2	0.72	0.43	1.20	0.98	0.69	1.39
Non-Hodgkins Lymphoma	13	0.6	0.77	0.31	1.92	1.10	0.58	2.09
Hodgkins lymphoma	8	0.4	1.81	0.72	4.53	1.56	0.71	3.43
Multiple myeloma	29	1.4	0.76	0.39	1.48	0.92	0.58	1.47

Standardized morbidity odds ratios (SMORs) adjusted for age and smoking, using two unexposed referent populations. Massachusetts Cancer Registry.

^aCancers for which evidence of an association with firefighting has been reported.

reporting of firefighter varied by cancer site. There are no data with which to investigate this possibility, but there is little reason to suspect that differential reporting of being a firefighter (or police) would occur by cancer site. This misclassification is likely to result in an underestimate of the association of firefighting and cancers.

A second limitation of registry-based studies is that occupation information was obtained from medical records, and so some misclassification of usual occupation was likely. But because of proud traditions and strong unions in these professions, we believe that firefighters and police are more likely than other occupations to be correctly identified in hospital records. A source of occupational misclassification particular to firefighters and police is that many may retire after 20 years and pursue a second career, longer than the first, which is recorded as the usual occupation. This could result in a bias if the firefighters with cancers of concern were less likely to pursue or continue a second career and thus were

more likely to be identified as a firefighter because of the disease. This bias, if present, would tend to skew the high SMORs into the lower age categories and would tend to elevate risks for short latency cancers. Neither of these patterns is evident in this study.

Even if occupational title was correctly recorded, this will not accurately correspond to carcinogenic exposures that may occur in the work environment, and so there will be another type of misclassification from the necessary equating of usual occupation with actual hazard. It has been estimated that only about two-thirds of fire department personnel are directly engaged in fighting fires [Austin et al., 2001a]. Thus grouping all firefighters together, regardless of types of fires fought, years on the job, and so on, would tend to dilute the effects of exposure and probably result in underestimates of any true occupational cancer risks.

Registry-based studies need to deal with the problem of choosing appropriate comparisons. There are two such

TABLE III. Age Stratified Cancer Risk Among Massachusetts Firefighters, 1987–2003

Age	18–54			55–74			75+		
	SMORs	95% CI		SMORs	95% CI		SMORs	95% CI	
Lip	— ^a	—	—	1.23	0.20	7.58	<0.01	<0.01	>99.99
Buccal cavity	1.07	0.27	4.28	0.59	0.25	1.40	0.69	0.12	3.84
Nasopharynx	—	—	—	0.88	0.12	6.46	—	—	—
Esophagus	1.30	0.52	3.24	0.70	0.41	1.20	1.58	0.56	4.42
Stomach	2.02	0.57	7.15	0.73	0.41	1.27	0.94	0.38	2.36
Colon	1.05	0.55	1.99	1.24	0.85	1.81	1.73	1.06	2.84
Rectum	0.97	0.39	2.46	0.94	0.57	1.57	0.70	0.31	1.56
Liver	—	—	—	1.02	0.41	2.53	1.77	0.46	6.88
Pancreas	0.70	0.22	2.16	0.88	0.47	1.65	1.12	0.37	3.34
Larynx	0.29	0.08	1.06	0.76	0.39	1.45	0.78	0.25	2.45
Lung	0.82	0.44	1.50	1.03	0.74	1.43	1.05	0.63	1.76
Skin melanoma	0.97	0.51	1.88	0.61	0.33	1.13	0.35	0.13	0.91
Soft tissue sarcoma	1.41	0.33	6.09	1.72	0.38	7.89	0.58	0.15	2.21
Breast	—	—	—	0.42	0.04	4.72	—	—	—
Prostate	1.14	0.65	2.00	1.05	0.78	1.43	0.91	0.58	1.43
Testicular	1.21	0.60	2.45	1.40	0.09	23.08	—	—	—
Kidney	1.74	0.78	3.89	1.15	0.68	1.96	1.41	0.48	4.16
Bladder	1.28	0.49	3.30	1.12	0.73	1.70	1.41	0.78	2.54
Brain	2.03	0.79	5.25	1.70	0.80	3.60	2.78	0.64	12.04
Thyroid	0.56	0.18	1.71	1.66	0.36	7.64	—	—	—
Leukemia	1.83	0.66	5.08	0.43	0.20	0.96	0.49	0.17	1.44
Non-Hodgkins Lymphoma	1.18	0.26	5.36	0.83	0.23	2.96	—	—	—
Hodgkins lymphoma	2.86	0.76	10.74	1.27	0.30	5.47	0.91	0.06	15.21
Multiple myeloma	0.68	0.13	3.54	0.75	0.32	1.74	0.76	0.17	3.36

Standardized morbidity odds ratios (SMORs) adjusted for age and smoking, using police as the referent population.

Massachusetts Cancer Registry.

^aInsufficient data.

choices to make: an “unexposed” population, and a reference disease group. The former is meant to represent the study group, absent the hypothesized hazardous exposure. We used two unexposed populations: police and all other occupations. The former has the advantage that selection pressures like hiring rules and pre-employment health examinations are fairly comparable. Also, job benefits like health insurance and pay scales are usually similar, and both police and firefighter have similar healthy worker effects. Thus the use of police as a comparison population may improve validity by making the two groups comparable on a number of health-related characteristics. On the other hand, perhaps police and firefighters share many of the same exposures—police often respond to fire calls, for example—and thus police may not represent an unexposed population relative to firefighters. A second “unexposed group”—all cases with known occupations, seemed like it might be useful as well. The results were fairly similar in the two different unexposed groups (Table II), so we chose to focus our analyses on the police, which we regarded as the more valid comparison group.

The reference disease group includes all white, male cases with cancer sites that are unrelated to the exposures of interest. Because all of the data come from a cancer registry there are no non-diseased subjects available for comparison, however, the occupational experience of cancer cases from sites *unrelated* to the exposures of interest can be used to represent the general population from which the cases come. Many cancer sites have been associated with firefighting in one or more studies, and so we selected as reference sites all cancers that were not on the list of cancer of concern. If we erred by including in the reference sites a cancer that is actually elevated among firefighters, then this will bias observed associations towards the null.

Sites With Evidence of Elevated Risk

Recent reviews identified strong evidence of an association between firefighting and a number of cancers, including leukemia, non-Hodgkin's lymphoma, multiple myeloma, brain and bladder cancer; and weaker but plausible

evidence for cancers of the rectum, colon, stomach, prostate, melanoma [Golden et al., 1995; Bogucki and Rabinowitz, 2005]. The findings from the Massachusetts Cancer Registry are compatible with this list. The strongest associations between cancer and firefighting were found for cancers of the colon and brain (Tables II and III). Bladder cancer was modestly elevated, although confidence intervals included the null, and Hodgkin's lymphoma was also elevated, albeit with wide confidence intervals.

Elevated colon cancer in firefighters has been reported in several other studies [Vena and Fiedler, 1987; Demers et al., 1992; Guidotti, 1993; Baris et al., 2001]. Possible carcinogens of colon cancer are asbestos and PAHs [Siemiatycki et al., 2004], both of which are found in the work environment of firefighters [Markowitz et al., 1992; Golden et al., 1995; Austin, 2001a,b; Caux et al., 2002].

Possible brain carcinogens to which firefighters may be exposed include vinyl chloride, benzene, *n*-hexane, PAHs, PCBs, *N*-nitroso compounds, lead, arsenic and mercury [Beall et al., 2001; Navas-Acien et al., 2002; Pan et al., 2005; Schlehofer et al., 2005; Pasetto et al., 2006; van Wijngaarden and Dosemeci, 2006].

The previous Massachusetts Cancer Registry study (covering the years 1982–1986) found a higher risk of bladder cancer (SMOR = 2.11, 95% CI: 1.07–4.14) than was observed in these data covering the subsequent 16 years (SMOR = 1.22, 95% CI: 0.89–1.69) [Sama et al., 1990]. Several other studies of firefighters have found excess bladder cancer [Vena and Fiedler, 1987; Guidotti, 1993; Ma et al., 2005]. Bladder carcinogens produced during building fires include PAHs, soot, diesel exhaust, and organic solvents [Boffetta et al., 1997; Boffetta and Silverman, 2001; Bosetti et al., 2005; Kellen et al., 2006].

The earlier Massachusetts study reported an elevated risk of melanoma in firefighters. The current study did not find much evidence for this—there was only an elevated risk in the youngest age group, 18–54 years, when compared to the all other occupations referent. Several other studies have found excess melanoma in firefighters [Feuer and Rosenman, 1986; Demers et al., 1992, 1994].

We did not observe an excess of non-Hodgkin's lymphoma which was found in the earlier Massachusetts study, but instead observed some evidence for an elevated risk of Hodgkin's lymphoma, although the numbers were small and confidence intervals rather wide.

Differences Between 1982–1986 and 1987–2003

This study followed closely the methods and data sources of an earlier study [Sama et al., 1990]. There are several notable differences between the results for the two time periods. In the first study, melanoma, bladder

cancer, and Hodgkin's lymphoma were elevated in firefighters. These excesses were largely reduced in the study of the subsequent 16 years, while colon and brain cancer were elevated. The reasons for these changes are unknown. It is certainly possible that there have been important changes in the chemical composition of combustion products, as building materials change. The baseline health of firefighters has probably also changed, and there may be important but unmeasured shifts in nutritional or other factors that change underlying risk.

Despite these important changes however, there continue to be elevated cancer risks among firefighters, and these risks are consistent with other studies of firefighters.

REFERENCES

- Aronson KJ, Tomlinson GA, Smith L. 1994. Mortality among firefighters of metropolitan Toronto. *Am J Ind Med* 26:89–101.
- Austin CC, Ecobichon DJ, Dussault G. 2001a. Characterization of volatile organic compounds in smoke at experimental fires. *J Toxic Environ Health* 63:191–206.
- Austin CC, Wang D, Ecobichon DJ, Dussault G. 2001b. Characterization of volatile organic compounds in smoke at municipal structural fires. *J Toxicology Environ Health* 63:437–458.
- Baris D, Garrity TJ, Telles JL, Heineman EF, Olshan A, Zahm SH. 2001. Cohort mortality study of Philadelphia firefighters. *Am J Ind Med* 39:463–476.
- Bates MN, Fawcett J, Garrett N, Arnold R, Pearce N, Woodward A. 2001. Is testicular cancer an occupational disease of fire fighters? *Am J Ind Med* 40:263–270.
- Beall C, Delzell E, Rodu B, Sathikumar N, Lees PS, Breyse PN, Meyers M. 2001. Case-control study of intracranial tumors among employees at a petrochemical research facility. *J Occup Environ Med* 43:1103–1113.
- Bendix S. 1979. Firefighters exposure to environmental carcinogens. *J Combust Toxic* 6:127–135.
- Boffetta P, Silverman DT. 2001. A meta-analysis of bladder cancer and diesel exhaust exposure. *Epidemiology* 12:125–130.
- Boffetta P, Jourenkova N, Gustavsson P. 1997. Cancer risk from occupational and environmental exposure to polycyclic aromatic hydrocarbons. *Cancer Causes Control* 8:444–472.
- Bogucki S, Rabinowitz PM. 2005. Occupational health of police and firefighters. In: Rosenstock L, Cullen MR, Brodtkin CA, editors. *Textbook of clinical occupational and environmental medicine* 2nd edition. Philadelphia: Elsevier Saunders. p 272–281.
- Bosetti C, Pira E, La Vecchia C. 2005. Bladder cancer risk in painters: A review of the epidemiological evidence, 1989–2004. *Cancer Causes Control* 16:997–1008.
- Brand-Rauf PW, Fallon LF, Tarantini T, Idema C, Andrews L. 1988. Health hazards of fire fighters: Exposure assessment. *Br J Ind Med* 45:606–612.
- Brand-Rauf PW, Cosman B, Fallon LF, Tarantini T, Idema C. 1989. Health hazards of fire fighters: Exposure assessment. *Br J Ind Med* 46:209–211.
- Brownson RC, Chang JC, Davis JR. 1987. Occupation, smoking, and alcohol in the epidemiology of bladder cancer. *Am J Public Health* 77:1298–1300.

- Burgess JL, Crutchfield CD. 1995. Tucson firefighter exposure to products of combustion: A risk assessment. *Appl Occup Environ Hyg* 10:37–42.
- Burnett CA, Halperin WE, Lulich NR, Sestito JP. 1994. Mortality among fire fighters: A 27 state survey. *Am J Ind Med* 26:831–833.
- Caux C, O'Brien C, Viau C. 2002. Determination of firefighter exposure to polycyclic aromatic hydrocarbons and benzene during fire fighting using measurement of biological indicators. *Appl Occup Environ Hyg* 17:379–386.
- Checkoway H, Pearce N, Kriebel D. 2004. Research methods in occupational epidemiology. New York: Oxford. p 247–262.
- Demers PA, Heyer NJ, Rosenstock L. 1992. Mortality among firefighters from three northwestern United States Cities. *Br J Ind Med* 49:664–670.
- Demers PA, Checkoway H, Vaughan TL. 1994. Cancer incidence among firefighters in Seattle and Tacoma, Washington (United States). *Cancer Causes Control* 5:129–135.
- Feuer E, Rosenman K. 1986. Mortality in police and firefighter in New Jersey. *Am J Ind Med* 2:43–50.
- Fitzgerald EF, Standfast SJ, Youngblood LG, Melius JM, Janerich DT. 1986. Assessing the health effects of potential exposure to PCBs, dioxins, and furans from electrical transformer fires: The Binghamton state Office Building medical surveillance program. *Arch Environ Health* 41:368–376.
- Froines JR, Hinds WC, Duffy RM, La Fuente EJ, Lia WC. 1987. Exposure of fire fighters to diesel emissions in fire stations. *Am Ind Hyg Assoc J* 48:202–207.
- Golden AL, Markowitz SB, Landrigan PJ. 1995. The risk of cancer in firefighters. *Occup Med* 10:803–820.
- Guidotti TL. 1993. Mortality of urban firefighters in Alberta, 1927–1987. *Am J Ind Med* 23:921–940.
- Guidotti TL. 1995. Occupational mortality among firefighters: Assessing the association. *J Occup Environ Med* 37:1348–1356.
- Haas NS, Gochfeld M, Robson MG, Wartenberg D. 2003. Latent health effects in firefighters. *Int J Occup Environ Health* 9:95–103.
- Heyer N, Weiss NS, Demers P, Rosenstock L. 1990. Cohort mortality study of Seattle firefighters: 1945–1983. *Am J Ind Med* 17:493–504.
- Jankovic J, Jones W, Burkhart J, Noonan G. 1992. Environmental study of firefighters. *Ann Occup Hyg* 35:581–602.
- Kellen E, Zeegers M, Paulussen A, Vlietinck R, Vlem EV, Veulemans H, Buntinx F. 2007. Does occupational exposure to PAHs, diesel and aromatic amines interact with smoking and metabolic genetic polymorphisms to increase the risk on bladder cancer?; The Belgian case control study on bladder cancer risk. *Cancer Lett* 245:51–60.
- Ma F, Lee DJ, Fleming LE, Dosemeci M. 1998. Race-specific cancer mortality in US firefighters: 1984–1993. *J Occup Environ Med* 40:1134–1138.
- Ma F, Fleming LE, Lee DJ, Trapido E, Gerace TA, Lai H, Lai S. 2005. Mortality in Florida professional firefighters. *Am J Ind Med* 47:509–517.
- Markowitz S, Garibaldi K, Lilis R, Landrigan PJ. 1992. Asbestos exposure and firefighting. *Ann NY Acad Sci* 643:573–576.
- Miettinen OS, Wang JD. 1981. An alternative to the proportionate mortality ratio. *Am J Epidemiol* 114:144–148.
- Moen BE, Ovrebo S. 2001. Assessment of exposure to polycyclic aromatic hydrocarbons during firefighting by measurement of urinary 1-hydroxypyrene. *J Occup Environ Med* 39:515–519.
- Muscat JE, Wynder EL. 1995. Diesel exhaust, diesel fumes, and laryngeal cancer. *Otolaryngol Head Neck Surg* 112:437–440.
- Navas-Acien A, Pollan A, Gustavsson P, Plato N. 2002. Occupation, exposure to chemicals and risk of glioma and meningioma in Sweden. *Am J Ind Med* 42:214–227.
- Pan SY, Ugnat AM, Mao Y. 2005. Canadian Cancer Registries Epidemiology Research Group. Occupational risk factors for brain cancer in Canada. *J Occup Environ Med* 47:704–717.
- Park RM, Nelson NA, Silverstein MA, Mirer FE. 1992. Use of medical insurance claims for surveillance of occupational disease. *J Occup Med* 34:731–737.
- Pasetto R, Bosco MG, Palange S, Comba P, De Santis M, Di Fabio M, Forastiere F, Magrelli F, Castellani G, Perucci CA, Rovetta S, Pirastu R. 2006. Mortality study of employees in a factory of recovery and refining of catalytic converters in Rome, Italy. *Ann Ist Super Sanita* 42:156–162.
- Sama SR, Martin TR, Davis LK, Kriebel D. 1990. Cancer incidents among Massachusetts firefighters, 1982–1996. *Am J Ind Med* 18:47–54.
- Schlehofer B, Hettinger I, Ryan P, Blettner M, Preston-Martin S, Little J, Arslan A, Ahlbom A, Giles GG, Howe GR, Menegoz F, Rodvall Y, Choi WN, Wahrendorf J. 2005. Occupational risk factors for low grade and high grade glioma: Results from an International case control study of adult brain tumours. *Int J Cancer* 113:116–125.
- Siemiatycki J, Richardson L, Straif K, Latreille B, Kakhani R, Campbell S, Rousseau MC, Boffetta P. 2004. Listing occupational carcinogens. *Environ Health Perspectives* 112:1447–1459.
- Smith KR, Kliever EV. 1995. Estimating standard mortality odds ratios with national mortality followback data. *Epidemiology* 6:55–60.
- Stang A, Jockel KH, Baumgardt-Elms C, Ahrens W. 2003. Firefighting and risk of testicular cancer: Results from a German Population-based Case-Control study. *Am J Ind Med* 43:291–294.
- Tornling G, Gustavsson T, Hogstedt C. 1994. Mortality and cancer incidence in Stockholm firefighters. *Am J Ind Med* 25:219–228.
- Treitman RD, Burgess WA, Gold A. 1980. Air contaminants encountered by fire fighters. *Am Ind Hyg Assoc J* 41:796–802.
- van Wijngaarden E, Dosemeci M. 2006. Brain cancer mortality and potential occupational exposure to lead: findings from the National Longitudinal Mortality Study, 1979–1989. *Int J Cancer* 119:1136–1144.
- Vena JE, Fiedler RC. 1987. Mortality of a municipal-worker cohort: IV. Firefighters. *Am J Ind Med* 11:671–684.