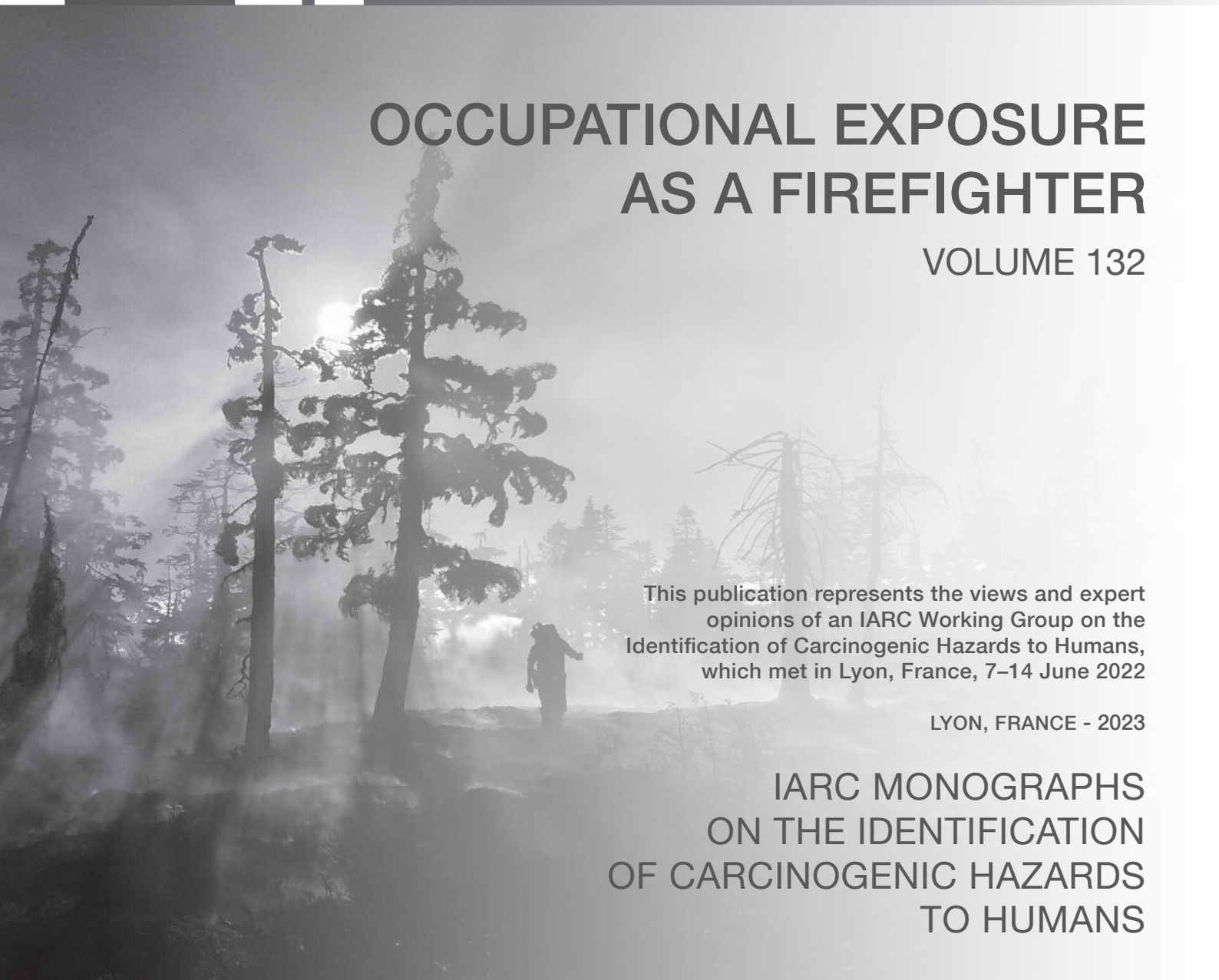
IARC MONOGRAPHS



OCCUPATIONAL EXPOSURE AS A FIREFIGHTER

VOLUME 132

This publication represents the views and expert opinions of an IARC Working Group on the Identification of Carcinogenic Hazards to Humans, which met in Lyon, France, 7–14 June 2022

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IARC MONOGRAPHS ON THE IDENTIFICATION OF CARCINOGENIC HAZARDS TO HUMANS

International Agency for Research on Cancer

World Health Organization

Table S2.2 Cohort and case–control studies only reporting having ever worked as a firefighter and cancers of the lung and respiratory system, including mesothelioma

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Amadeo et al. (2015) France Enrolment, 1 January 1979/ follow-up, 1979–2008 Cohort	10 829 male professional [career] firefighters employed in France on 1 January 1979, identified from 89 French administrative departments (93% of population) Exposure assessment method: ever employed as firefighter from employment records	Larynx and trachea, mortality Bronchus and lung, mortality Mesothelioma, mortality	SMR (French population referent): Firefighters SMR (French population referent): Firefighters SMR (French population referent): Firefighters	28 187 6	1.10 (0.73–1.59) 0.86 (0.74–0.99) NR	Age, calendar year	*Exposure assessment critique*: Minimal quality. Exposure assessment only one point in time. Employed as any type of paid [career] firefighter. May include municipal and rural firefighters. *Strengths*: cohort coverage at the national level; relatively large cohort with long follow-up; robust linkages. *Limitations*: probable healthy-worker selection bias; includes only the 16% who were career civilian firefighters. (79% were volunteers and 5% were military); lack of information on exposure and potential confounders.

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Deschamps et al. (1995) Paris, France Enrolment, 1 January 1977/ follow-up, 1977 to 1 January 1991 Cohort	830 male professional [career] firefighters with ≥ 5 yr of service in the Paris Fire Brigade before 1977 Exposure assessment method: employed as firefighter with ≥ 5 yr of active fire combat duty from employment records	Respiratory system, mortality	SMR (French population referent): Firefighters	7	1.12 (0.45–2.30)	Age, calendar year	*Exposure assessment critique*: Satisfactory quality. Duration of active fire combat assessed only for deaths, not used in analyses. Municipal firefighters. *Strengths*: complete cohort enumeration. *Limitations*: small study size; probable healthy-worker selection bias; lack of information on exposure and potential confounders; probabilistic linkage of outcome data.
Ma et al. (2006) Florida, USA Enrolment, 1972–1999/ follow-up, 1981–1999 Cohort	36 813; all male (34 796) and female (2017) professional [career] firefighters certified in Florida in 1972–1999; the certification date was considered to be the date of first exposure Exposure assessment method: ever career firefighter from professional certification records	Larynx, incidence	SIR (Florida population referent): Male firefighters Female firefighters	20 0	0.73 (0.44–1.12) 0 (NR)	Age, calendar year	*Exposure assessment critique*: Minimal quality. Only one point in time measure of exposure, no indication when exposure stopped. May include municipal and rural firefighters. *Strengths*: assesses cancer incidence; includes female firefighters; large male cohort. *Limitations*: probable healthy-worker selection bias; small female cohort; young age at end of follow-up; lacks information on exposure and potential confounders.
		Bronchus and lung, incidence	SIR (Florida population referent): Male firefighters Female firefighters	128 3	0.65 (0.54–0.78) 1.51 (0.30–4.40)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Ma et al. (2005) Florida, USA Enrolment, 1972–1999/ follow-up, 1972–1999 Cohort	36 813; all male (34 796) and female (2017) professional [career] firefighters certified in Florida in 1972–1999 Exposure assessment method: ever career firefighter from professional certification records	Respiratory system, mortality	SMR (Florida population referent):			Age, calendar period	*Exposure assessment critique*: Minimal quality. Only one point in time measure of exposure, no indication when exposure stopped. May include municipal and rural firefighters. *Strengths*: includes female firefighters; large male cohort; multiple linkages to assess vital status; conducted a sensitivity analysis among firefighters with longest tenure (certified 1972–1976). *Limitations*: probable healthy-worker selection bias; small female cohort; young age at end of follow-up; lacks information on exposure and potential confounders.
			Male firefighters	155	0.88 (0.75–1.03)		
			Male firefighters certified 1972–1976	134	0.9 (0.76–1.07)		
			Female firefighters	3	2.16 (0.43–6.31)		
		Bronchus and lung (ICD-10, C34), mortality	SMR (Florida population referent):				
			Male firefighters	155	0.93 (0.79–1.09)		
			Male firefighters certified 1972–1976	134	0.96 (0.80–1.13)		
			Female firefighters	3	2.22 (0.45–6.49)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Grimes et al. (1991) Honolulu, Hawaii, USA 1969–1988 Cohort	205 deaths; all male firefighters with ≥ 1 yr of service in the City of Honolulu Fire Department Exposure assessment method: death certificate coding of usual occupation	Respiratory system, mortality	PMR (state population referent): All firefighters Caucasian [White] firefighters Hawaiian firefighters	 [18] [6] [9]	 1.28 (0.82–2.00) 1.09 (0.51–2.36) 0.96 (0.51–1.79)	NR	*Exposure assessment critique*: Minimal quality. Crude, relying on knowledge of usual occupation by death certifier. Possible differential misclassification from missing occupation on death certificates. May include municipal and rural firefighters. *Strengths*: long follow-up; examined risk by ethnic group (White/Hawaiian). *Limitations*: probable healthy-worker selection bias; unclear if underlying assumption that PMR will estimate an SMR is valid in this cohort; PMRs were not standardized by age or calendar period; no information on exposure and potential confounders. *Other comments*: number of deaths calculated by the Working Group.

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Musk et al. (1978) Boston, Massachusetts, USA 1915–1975 Cohort	5655 male professional [career] firefighters employed by the Boston Fire Department for ≥ 3yr since 1915 Exposure assessment method: employed as municipal firefighter for ≥ 3 yr from employment records	Respiratory system, mortality	SMR (Massachusetts population referent): Firefighters	70	[0.88 (0.69–1.10)]	Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Ever employed as municipal firefighter. *Strengths*: long follow-up. *Limitations*: probable healthy-worker selection bias; lack of information on cause for a proportion of deaths; lack of information on exposure and potential confounders.
Giles et al. (1993) Melbourne, Australia Enrolment, 1917–1989/ follow-up, 1980–1989 Cohort	2865 operational active male firefighters employed between 1917 and 1989 by the Metropolitan Fire Brigade in Melbourne, Australia Exposure assessment method: ever employed from employment records	Trachea, bronchus and lung, incidence	SIR (Victoria population referent): Firefighters	6	0.77 (0.28–1.68)	Age, calendar period	*Exposure assessment critique*: Minimal quality. Only ever municipal firefighter exposure. *Strengths*: assesses cancer incidence. *Limitations*: probable healthy-worker selection bias; small cohort size; no description of registry linkage methods; lack of information on exposure and potential confounders.

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Eliopulos et al. (1984) Western Australia Follow-up, 1939–1978 Cohort	990; all men employed as permanent full-time firefighters by the Western Australian Fire Brigade between October 1939 and December 1978 Exposure assessment method: records; ever employed as a permanent full-time firefighter, and categorical employment duration (years) as firefighters from employment records	Respiratory cancer, mortality	SMR (Western Australia referent) Employment as firefighter	7	0.84 (0.33–1.71)	Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Unsure whether permanent full-time status was maintained throughout study period. Municipal firefighters. *Strengths*: long follow-up time; low loss to follow-up. *Limitations*: probable healthy-worker selection bias; small study size; no personal information on exposure or potential confounders.
		Respiratory cancer, mortality	PMR (Western Australia referent): Employment as firefighter	7	1.04 (0.42–2.13)	Age, calendar period	
Zhao et al. (2020) Spain Enrolment, 2001/follow-up, 2001–2011 Cohort	9 579 759 (27 365 firefighters) men identified as residing in Spain on 1 November 2001, employed on the census date, and aged 20–64 yr at baseline; followed for mortality using a national death registry Exposure assessment method: questionnaire; employed as firefighter in week before census	Larynx, mortality	Occupation (MRR): All other occupations	3291	1	Age	*Exposure assessment critique*: Minimal quality. Firefighting self-reported at one point in time. Years of firefighting, may include municipal and rural firefighters. *Strengths*: large study size; low loss to follow-up; cohort coverage at the national level. *Limitations*: occupation determined by self-report at baseline; short follow-up and young cohort age; lack of information on exposure and potential confounders.
			Firefighters	14	1.77 (1.01–3.09)		
		Lung, mortality	Occupation (MRR): All other occupations	42 056	1	Age	
			Firefighters	104	0.94 (0.77–1.15)		
		Mesothelioma, mortality	Occupation (MRR): All other occupations	635	1	Age	
			Firefighters	1	0.62 (0.09–4.42)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Pukkala et al. (2014) Denmark, Finland, Iceland, Norway, Sweden 1961–2005 Cohort	16 422 male professional [career] firefighters in the NOCCA cohort (a registry-based cohort study of Nordic country residents who participated in any computerized population census (1960, 1970, 1980/81, or 1990) and were followed up through linkage to national cancer registries), aged 30–64 yr, alive, and in the country in the year following census participation Exposure assessment method: records; employed as firefighter at time of census	Larynx, incidence	SIR (national referent):			Country, age, calendar period	*Exposure assessment critique*: Satisfactory quality. Self-reported firefighter as current job. Includes municipal and rural firefighters. *Strengths*: large study size; long follow-up time; assesses cancer incidence using high-quality outcome data; contrasts by country, observation period, and age; analyses by lung cancer histology; multiple sensitivity analyses. *Limitations*: probable healthy-worker selection bias; lack of information on exposure and potential confounders.
			Firefighters	31	1.06 (0.72–1.50)		
		Lung, incidence	SIR (national referent):				
			Firefighters	310	0.97 (0.87–1.09)		
		Lung, incidence	Country (SIR):			Age, calendar period	
			Denmark	56	1.37 (1.03–1.77)		
			Finland	71	0.76 (0.60–0.97)		
			Iceland	3	0.91 (0.19–2.66)		
			Norway	87	1.18 (0.95–1.46)		
			Sweden	93	0.87 (0.70–1.06)		
		Lung, incidence	Age at follow-up (SIR):			Country, age, calendar period	
			30–49 yr	15	0.76 (0.43–1.25)		
			50–69 yr	154	0.82 (0.69–0.96)		
			≥ 70 yr	141	1.28 (1.08–1.52)		
		Lung, incidence	Follow-up period (SIR):				
			1961–1975	27	0.92 (0.60–1.33)		
			1976–1990	109	0.90 (0.74–1.09)		
			1991–2005	174	1.04 (0.89–1.21)		
		Lung (SCC), incidence	SIR (national referent):				
			Firefighters	90	0.88 (0.71–1.08)		
		Lung (adenocarcinoma), incidence	SIR (national referent):				
			Firefighters	80	1.29 (1.02–1.60)		
		Lung (adenocarcinoma), incidence	Country (SIR):			Age, calendar period	
			Denmark	16	1.90 (1.09–3.08)		
			Finland	15	1.03 (0.58–1.71)		
			Iceland	0	0 (0.00–3.88)		
			Norway	22	1.55 (0.97–2.34)		
			Sweden	27	1.13 (0.74–1.64)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Pukkala et al. (2014) (cont.)		Lung (adenocarcinoma), incidence	Age at follow-up (SIR):			Country, age, calendar period	
			30–49 yr	2	0.40 (0.05–1.46)		
			50–69 yr	41	1.09 (0.78–1.48)		
			≥ 70 yr	37	1.90 (1.34–2.62)		
		Lung (adenocarcinoma), incidence	Follow-up period (SIR):				
			1961–1975	4	1.19 (0.32–3.05)		
			1976–1990	26	1.27 (0.83–1.87)		
			1991–2005	50	1.31 (0.97–1.72)		
		Lung (small cell/ oat cell), incidence	SIR (national referent):				
			Firefighters	34	0.83 (0.58–1.16)		
		Mesothelioma, incidence	SIR (national referent):				
			Firefighters	17	1.55 (0.90–2.48)		
		Mesothelioma, incidence	Country (SIR):				
			Denmark	1	0.92 (0.02–5.13)		
			Finland	4	1.55 (0.42–3.98)		
			Iceland	0	0 (0.00–44.45)		
			Norway	6	2.78 (1.02–6.06)		
			Sweden	6	1.18 (0.43–2.58)		
		Mesothelioma, incidence	Age at follow-up (SIR):				
			30–49 yr	1	1.02 (0.03–5.69)		
			50–69 yr	6	0.98 (0.36–2.13)		
			≥ 70 yr	10	2.59 (1.24–4.77)		
		Mesothelioma, incidence	Follow-up period (SIR):				
			1961–1975	0	0 (0.00–10.5)		
			1976–1990	5	1.56 (0.51–3.64)		
			1991–2005	12	1.62 (0.84–2.83)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Sritharan et al. (2022) Ontario, Canada Enrolment, 1983–2019; follow-up, 1983–2020 Cohort	2 368 226 (firefighters, 13 642; police, 22 595); workers aged ≥ 15 yr who submitted lost-time workers' compensation injury and disease claims to the Workplace Safety and Insurance Board with known sex, birthdate, claim date, and occupation and industry information; incident cases identified using the Ontario Cancer registry Exposure assessment method: employed as firefighter at time of workers' compensation claim	Larynx, incidence	Referent (HR):			Age at start of follow-up, birth year, sex	*Exposure assessment critique*: Minimal quality. Duration of firefighter work unclear. May include full-time, part-time, municipal. and rural firefighters. *Strengths*: large study size; long follow-up time; includes female firefighters; working population used as referent; assesses cancer incidence. *Limitations*: potential selection bias into claims database, as compensation claims used to identify the cohort may differ by occupation; lack of information on exposure and potential confounders.
			Firefighters vs all other workers	15	0.68 (0.41–1.13)		
			Firefighters vs police	15	1.09 (0.54–2.18)		
		Lung, incidence	Referent (HR):				
			Firefighters vs all other workers	210	0.84 (0.74–0.97)		
			Firefighters vs police	210	1.11 (0.92–1.35)		
		Mesothelioma, incidence	Referent (HR):				
			Firefighters vs all other workers	11	1.56 (0.86–2.84)		
			Firefighters vs police	11	3.21 (1.01–10.20)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Harris et al. (2018) Canada Enrolment, 1991/follow-up, 1992–2010 Cohort	CanCHEC: 1 108 410 (4535 firefighters) men participating in the long form Canadian census in 1991, employed with a valid occupation and aged 25–74 yr at cohort entry; incident cancers identified using a national cancer registry Exposure assessment method: questionnaire; ever employed as firefighter data from census	Lung, incidence	Occupation (HR): Non-firefighters Firefighters	 NR 65	 1 0.97 (0.77–1.24)	Age, region	*Exposure assessment critique*: Minimal quality. Self-reported firefighter as current or longest job. Includes municipal and rural firefighters. *Strengths*: study size; long follow-up time; national coverage of working population; assesses cancer incidence. *Limitations*: occupation determined at 1991 census based on self-report. Lack of information on exposure and potential confounders.
		Lung, incidence	Occupation (HR): Non-firefighters Firefighters	 NR 65	 1 0.90 (0.71–1.15)	Age, region, education	
Lee et al. (2020) Florida, USA 1981–2014 Case–control	Cases: firefighters, 3760 men, 168 women; non-firefighters, NR; cancer patients identified via linkage of the FCDS and FMO records on firefighter certification and employment Controls: varied by cancer site; controls were patients with all other cancer types except the cancer of interest; additional control exclusions excluded selected tobacco-associated cancers (lung, larynx, oesophagus, bladder, oral/ pharynx).	Larynx, incidence	Group (OR for firefighters vs non-firefighters): Men Men, with additional control exclusions Women	 35 35 0	 0.48 (0.34–0.67) 0.46 (0.33–0.64) 0 (NR)	Age, year of diagnosis	*Exposure assessment critique*: Satisfactory quality. Ever firefighter exposure only. May include municipal and rural firefighters. *Strengths*: large study size (male firefighters); reliable information on firefighting status; includes female firefighters; assesses cancer incidence including tumour staging.
		Larynx, incidence	Tumour stage, men (OR for firefighters vs non-firefighters) Early-stage Late-stage	 29 < 10	 0.62 (0.43–0.90) 0.18 (0.07–0.48)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Lee et al. (2020) (cont.)	Exposure assessment method: employment as firefighter from employment and professional certification records	Larynx, incidence	Age at diagnosis, men (OR for firefighters vs non-firefighters):			Age, year of diagnosis	*Limitations*: few female firefighters; cancer cases selected as controls (numerator-based analysis); limited information on exposure and potential confounders.
			< 50 yr	< 10	0.53 (0.26–1.06)		
			≥ 50 yr	< 10	0.46 (0.31–0.67)		
		Lung, incidence	Group (OR for firefighters vs non-firefighters):				
			Men	466	0.79 (0.72–0.87)		
			Men, with additional control exclusions	466	0.77 (0.69–0.84)		
			Women	10	0.54 (0.28–1.02)		
		Lung, incidence	Tumour stage, men (OR for firefighters vs non-firefighters):				
			Early stage	73	0.68 (0.54–0.86)		
			Late-stage	343	0.93 (0.82–1.05)		
		Lung, incidence	Age at diagnosis, men (OR for firefighters vs non-firefighters):				
			< 50 yr	50	0.59 (0.44–0.78)		
			≥ 50 yr	416	0.82 (0.74–0.91)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Lee et al. (2020) (cont.)		Mesothelioma, incidence	Group (OR for firefighters vs non-firefighters):			Age, year of diagnosis	
			Men	11	1.26 (0.70–2.29)		
			Men, with additional control exclusions	11	1.19 (0.66–2.16)		
			Women	0	NC		
		Mesothelioma, incidence	Tumour stage, men (OR for firefighters vs non-firefighters):				
			Early-stage	< 10	0.90 (0.13–6.41)		
			Late-stage	< 10	1.84 (0.99–3.44)		
		Mesothelioma, incidence	Age at diagnosis, men (OR for firefighters vs non-firefighters):				
			< 50 yr	< 10	1.86 (0.46–7.51)		
			≥ 50 yr	< 10	1.18 (0.61–2.28)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
McClure et al. (2021) Florida, USA 1981–2014 Case–control	Cases: firefighters: 3760; non-firefighters: NR; male cancer patients identified via linkage of the FCDS and FMO records on firefighter certification and employment Controls: varied by cancer site; control patients are all other cancer types but the cancer of interest. Exposure assessment method: employment as firefighter from cancer registry records and from employment and professional certification records	Respiratory system, incidence	Occupation (OR): Non-firefighters Firefighters, FMO employment certification records Firefighters, FCDS occupational data	 NR 505 311	 1 0.73 (0.67–0.81) 0.99 (0.87–1.11)	Age, year of diagnosis	*Exposure assessment critique*: Minimal quality. Ever firefighter exposure only. Incorporation of employment and certification records improvement for method 2. May include municipal and rural firefighters. *Strengths*: large study size; assesses cancer incidence. *Limitations*: cancer cases selected as controls (numerator-based analysis); minimal information on exposure and potential confounders; completeness of occupation data (from registry records) varied by sociodemographic and diagnostic characteristics.

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Langevin et al. (2020) Boston, Massachusetts, USA 1999–2011 Case–control	Cases: 718 (larynx, 120) men with head and neck squamous cell carcinoma, from major teaching hospitals located in Boston, Massachusetts, and verified via cancer-registry records Controls: 905 controls with no prior history of head and neck cancer, enrolled using Massachusetts annual census records and frequency-matched to cases on age (± 3 yr), sex, and residence Exposure assessment method: duration (years) of employment as firefighter from coded interview	Larynx (SCC), incidence	Firefighter occupational history (OR):			Age, race, education, smoking status, alcohol consumption, residence	*Exposure assessment critique*: Satisfactory quality. Possible recall bias for duration of active firefighter work. May include municipal and rural firefighters. *Strengths*: assesses incident cancers; analysis adjusting for several important risk factors, such as age, race, education, smoking and alcohol consumption, is a notable strength. *Limitations*: few firefighters participated in the study, stratified analyses were adversely affected by small numbers; potential for bias from self-report; potential for bias from selection, given firefighters were less likely to participate as controls.
			Never	117	1		
			Ever	3	1.70 (0.45–6.41)		
			Per decade as firefighter	3	1.07 (0.64–1.80)		
		Hypopharynx and larynx combined (SCC), incidence	Firefighter occupational history (OR):				
			Never	162	1		
			Ever	5	2.03 (0.67–6.15)		
			Per decade as firefighter	5	1.17 (0.80–1.72)		
		Hypopharynx and larynx combined (SCC), incidence	Firefighter occupational history, < 18.4 pack-years of cigarette smoking (OR):				
			Never	33	1		
			Ever	3	8.06 (1.74–37.41)		
			Per decade as firefighter	3	2.10 (1.06–4.14)		
		Hypopharynx and larynx combined (SCC), incidence	Firefighter occupational history, > 18.4 pack-years of cigarette smoking (OR):				
			Never	129	1		
			Ever	2	0.92 (0.17–5.01)		
			Per decade as firefighter	2	1.00 (0.58–1.73)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Muegge et al. (2018) Indiana, USA 1985–2013 Case–control	Cases: firefighters, 857; non-firefighters, 11 272; cancer as the underlying cause of death in state death registry among registrants with complete information on year of death, age at time of death, sex, race, ethnicity, industry code, and occupation code; all firefighter cancers were included, but non-firefighter cancers only observed among non-firefighter decedents matched 4:1 to firefighter decedents on age at death, sex, race, ethnicity, and year of death Controls: varied by cancer site; decedents with a cause of death other than the one under study among all firefighter decedents and a sample of non-firefighter decedents matched 4:1 to firefighter decedents on age at death, sex, race, ethnicity, and year of death Exposure assessment method: death certificate coding of usual occupation	Respiratory system, mortality	Death certificate occupation (OR): Non-firefighters Firefighters	 1157 318	 NR	Sex, race, ethnicity, age at death, year of death	*Exposure assessment critique*: Minimal quality. Crude, relying on knowledge of usual occupation by death certifier. Possible differential misclassification from missing occupation on death certificates. May include municipal and rural firefighters. *Strengths*: large study size. *Limitations*: poor reporting of some results; deaths used as controls (numerator-based analysis); lack of information on exposure and potential confounding.

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Tsai et al. (2015) California, USA 1988–2007 Case–control	Cases: 678 132 (all cancers); all first malignant primary cancers in the registry restricted to adult men (age 18–97 yr) with industry and occupation information available; sites must have ≥ 10 firefighters among the cases to be analysed Controls: 48 725; cancers of the pharynx, stomach, liver, and pancreas, in the registry, restricted to adult male participants (aged 18–97 yr) with industry and occupation information available Exposure assessment method: employment as firefighter, coded as longest job held from cancer registry	Larynx, incidence	Race (OR, firefighters vs non-firefighters):			Age, year of diagnosis, race	*Exposure assessment critique*: Minimal quality. Ever firefighter exposure only. May include municipal and rural firefighters. *Strengths*: large study size; assesses incident cancers, with subtypes reported for lung cancer; findings stratified by race/ethnicity. *Limitations*: no information on the population at risk (numerator-based analysis); occupation missing from nearly 50% of registry cases and more likely for people who were older or of Hispanic ethnicity; lack of information on exposure and potential confounders.
			White	25	0.64 (0.42–0.97)		
			Other	0	0 (NR)		
			Overall	25	0.59 (0.39–0.89)		
		Lung, incidence	Race (OR, firefighters vs non-firefighters):				
			White	506	1.10 (0.92–1.30)		
			Other	26	1.01 (0.57–1.78)		
			Overall	533	1.08 (0.92–1.28)		
		Lung (adenocarcinoma), incidence	Race (OR, firefighters vs non-firefighters):				
			White	164	1.11 (0.90–1.38)		
			Other	8	0.89 (0.40–2.00)		
			Overall	173	1.10 (0.89–1.35)		
		Lung (SCC), incidence	Race (OR, firefighters vs non-firefighters):				
			White	90	0.90 (0.70–1.17)		
			Other	5	0.78 (0.29–2.11)		
			Overall	95	0.89 (0.69–1.14)		
		Lung (small cell/ oat cell), incidence	Race (OR, firefighters vs non-firefighters):				
			White	81	1.30 (1.00–1.70)		
			Other	1	0.36 (0.05–2.71)		
			Overall	82	1.24 (0.95–1.61)		
		Lung (large cell; ICD-O-3, 8012–8014), incidence	Race (OR, firefighters vs non-firefighters):				
			White	25	0.89 (0.58–1.36)		
			Other	0	0 (NR)		
			Overall	25	0.84 (0.55–1.28)		
		Lung (non-specific non-small cell cancer; ICD-O-3, 8046), incidence	Race (OR, firefighters vs non-firefighters):				
			White	37	2.02 (1.34–3.04)		
			Other	5	2.42 (0.86–6.80)		
			Overall	42	2.01 (1.38–2.93)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Tsai et al. (2015) (cont.)		Mesothelioma, incidence	Race (OR, firefighters vs non-firefighters):			Age, year of diagnosis, race	
			White	19	1.34 (0.83–2.16)		
			Other	2	2.86 (0.67–12.28)		
			Overall	21	1.40 (0.89–2.21)		
Kang et al. (2008) Massachusetts, USA 1987–2003 Case–control	Cases: NR overall (firefighters, 1881; non-firefighters, NR); White male residents of Massachusetts aged ≥ 18 yr with complete information on "usual occupation" and a diagnosis with one of 25 "cancers of concern" in the MCR Controls: NR overall (firefighters, 244; non-firefighters, NR); white male residents of Massachusetts aged ≥ 18 yr with complete information on "usual occupation" and a cancer diagnosis not on the list of 25 "cancers of concern" in the MCR Exposure assessment method: employment as firefighter coded from longest job held from cancer registry	Larynx, incidence	Referent (SMBOR):			Age, smoking status	*Exposure assessment critique*: Minimal quality. Ever firefighter exposure only. May include municipal and rural firefighters. *Strengths*: large size; long study period; assesses incident cancers; smoking information available. *Limitations*: cancer cases used as controls (numerator-based analysis); incomplete information on occupation (38% missing); lack of information on exposure and potential confounders.
			Firefighters vs police	38	0.66 (0.39–1.10)		
			Firefighters vs all other occupations	38	0.81 (0.57–1.16)		
		Larynx, incidence	Age at diagnosis (SMBOR, firefighters vs police):				
			18–54 yr	NR	0.29 (0.08–1.06)		
			55–74 yr	NR	0.76 (0.39–1.45)		
			≥ 75 yr	NR	0.78 (0.25–2.45)		
		Lung, incidence	Referent (SMBOR):				
			Firefighters vs police	379	1.02 (0.79–1.31)		
			Firefighters vs all other occupations	379	0.91 (0.76–1.10)		
		Lung, incidence	Age at diagnosis (SMBOR, firefighters vs police):				
			18–54 yr	NR	0.82 (0.44–1.50)		
			55–74 yr	NR	1.03 (0.74–1.43)		
			≥ 75 yr	NR	1.05 (0.63–1.76)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Sama et al. (1990) Massachusetts, USA 1982–1986 Case–control	Cases: NR; White men aged ≥ 18 yr with information on usual occupation and a diagnosis with one of nine cancers of concern in the MCR Controls: NR; White men aged ≥ 18 yr with information on usual occupation and a cancer diagnosis for all other cancers, except those of the organ systems of concern (digestive, respiratory, and lymphatic/ haematopoietic) Exposure assessment method: employment as firefighter or fire chief from cancer registry records	Lung, incidence	Referent (SMBOR): Firefighters vs police Firefighters vs state	 71 71	 1.30 (0.84–2.03) 1.22 (0.87–1.69)	Age	*Exposure assessment critique*: Minimal quality. Ever firefighter exposure only. Use of secondary data sources confirmed occupation for some firefighters. May include municipal and rural firefighters. *Strengths*: assesses incident cancers; smoking information available. *Limitations*: small study; cancer cases used as controls (numerator-based analysis); incomplete information on occupation; crude smoking status information; no smoking adjustment; lack of information on exposure and potential confounders.

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Ma et al. (1998) USA 1984–1993 Case–control	Cases: NR; all male cancer deaths with coded industry and occupation on death certificates from 24 states captured in a NIOSH database Controls: NR; all male non-cancer deaths in the NIOSH database Exposure assessment method: death certificate coding of usual occupation	Larynx, mortality	Group, firefighters (MOR):			Year of death, age at death	*Exposure assessment critique*: Minimal quality. Crude, relying on knowledge of usual occupation by death certifier. Possible differential misclassification from missing occupation on death certificates. May include municipal and rural firefighters. *Strengths*: large study size (includes 6607 male firefighter deaths); broad geographical population coverage. *Limitations*: small number of cancer deaths among Black firefighters; non-cancer deaths used as controls (numerator-based analysis); lack of information on exposure and potential confounders.
			White	13	0.08 (0.4–1.3)		
			Black	0	NC		
		Lung, mortality	Group, firefighters (MOR):				
			White	633	1.1 (1.0–1.2)		
			Black	15	0.8 (0.5–1.3)		
		Pleura, mortality	Group, firefighters (MOR):				
			White	4	1.8 (NR)		
			Black	0	0 (NR)		

Table S2.2 (continued)

Reference, location, enrolment/ follow-up period, study design	Population size, description, exposure assessment method	Cancer type (histopathology), incidence or mortality	Exposure category or level	Exposed cases or deaths	Risk estimate (95% CI)	Covariates controlled	Comments
Burnett et al. (1994) USA 1984–1990 Mortality surveillance	5744 deaths among White male firefighters identified by evaluation of coded occupation on death certificates from 27 states Exposure assessment method: death certificate coding of usual occupation	Lung, mortality	Group (PMR): Firefighters Firefighters, age < 65 yr at death	 562 236	 1.02 (0.94–1.11) 0.98 (0.86–1.12)	Age	*Exposure assessment critique*: Minimal quality. Crude, relying on knowledge of usual occupation by death certifier. Possible differential misclassification from missing occupation on death certificates. May include municipal and rural firefighters. *Strengths*: large number of deaths; broad geographical population coverage. *Limitations*: numerator-only (PMR) analysis; errors in death-certificate occupation; lack of information on exposure or potential confounders.

CanCHEC, Canadian Census Health and Environment Cohort; CI, confidence interval; FCDS, Florida Cancer Data System; FMO, Office of the Florida State Marshal; HR, hazard ratio; ICD-10, International Classification of Diseases 10th revision; ICD-O-3, International Classification of Diseases for Oncology 3rd edition; MCR, Massachusetts Cancer Registry; MOR, mortality odds ratio; MRR, mortality rate ratio; NC, not calculated; NIOSH, National Institute for Occupational Safety and Health; NOCCA, Nordic Occupational Cancer study; NR, not reported; OR, odds ratio; PMR, proportionate mortality ratio; SCC, squamous cell carcinoma; SIR, standardized incidence ratio; SMBOR, standardized morbidity odds ratio; SMR, standardized mortality ratio; vs, versus; yr, year.

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