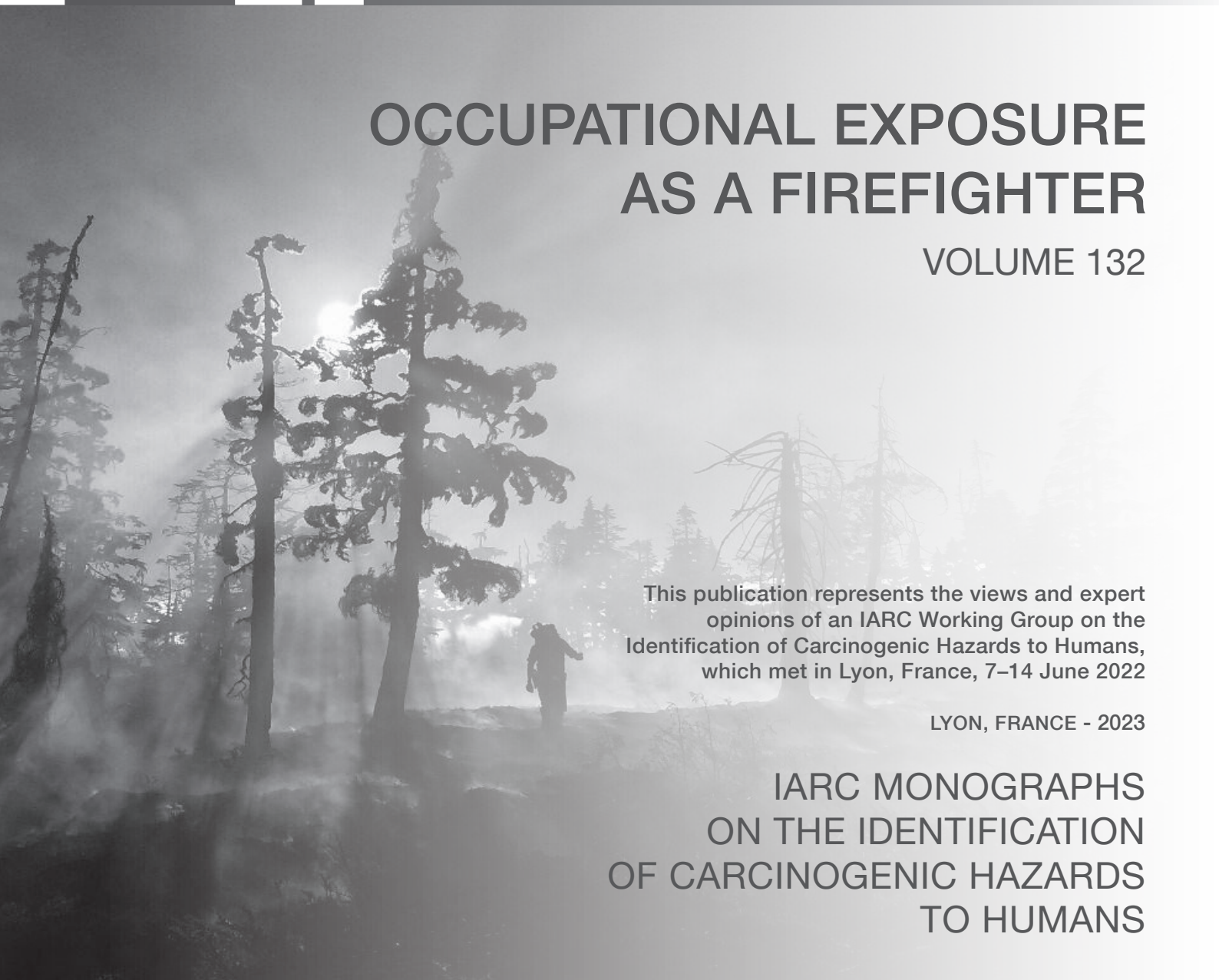
IARC MONOGRAPHS



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 S2.11 Cohort studies reporting occupational characteristics of firefighters and cancer of all sites combined

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
Ahn & Jeong (2015) Korea Enrolment, 1980–2007/follow-up, 1992–2007 Cohort	33 442 men employed as emergency responders for ≥ 1 mo between 1980 and 2007 with (29 453) and without (3989) firefighting experience and not deceased in 1991 Exposure assessment method: ever employed and categorical duration of employment (years) as first- or second-line firefighter and non-firefighters from employment records	All cancers combined, mortality	Duration of firefighting employment, 1-yr lag (SMR):			Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Heterogeneity of direct firefighter exposure within job title. May include both municipal and rural firefighters. *Strengths:* employment duration and internal comparison limits healthy-worker bias; only professional [career] firefighters were included in the cohort. *Limitations*: no information on personal characteristics or confounders; follow-up time was reasonably short; cohort members were fairly young; no direct measure of exposure.
			1 mo to < 10 yr	43	0.66 (0.48–0.89)		
			10 to < 20 yr	48	0.51 (0.38–0.68)		
			≥ 20 yr	76	0.59 (0.47–0.74)		
			Total	167	0.58 (0.50–0.68)		
		All cancers combined, mortality	Duration of firefighting employment, 1-yr lag (RR):				
			< 10 yr (including non-firefighters)	53	1		
			10 to < 20 yr	48	0.76 (0.51–1.12)		
			≥ 20 yr	76	1.54 (1.02–2.31)		

Table S2.11 (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
Ahn et al. (2012) Korea Enrolment, 1980–2007/follow-up, 1996–2007 Cohort	33 416 men employed as emergency responders for ≥ 1 mo between 1980 and 2007 with (29 438) and without (3978) firefighting experience and not deceased in 1995 Exposure assessment method: ever employed and categorical duration of employment (years) as first- or second-line firefighter and non-firefighters from employment records	All cancers combined, incidence	Duration of firefighting employment, 1-yr lag (SIR):			Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Heterogeneity of direct firefighter exposure within job title. May include rural and municipal firefighters. *Strengths*: employment duration and internal comparison limits healthy-worker bias; only professional [career] firefighters were included in the cohort. *Limitations*: no information on personal characteristics or confounders (except the firefighter cohort had a lower BMI and smoked less than the comparison population for the SIR analysis); follow-up time was reasonably short; cohort members were fairly young; no direct measure of exposure.
			1 mo to < 10 yr	122	1.00 (0.83–1.19)		
			≥ 10 yr	324	0.96 (0.86–1.07)		
			Total	446	0.97 (0.88–1.06)		
		All cancers combined, incidence	SRR:				
			Non-firefighters	40	1		
			Ever employed as a firefighter	446	0.83 (0.59–1.16)		

Table S2.11 (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
Marjerrison et al. (2022a) Norway Enrolment, 1950–2019/follow-up, 1960–2018 Cohort	3881 male professional [career] firefighters (most were full-time) employed in positions entailing active firefighting at any of 15 fire departments between 1950 and 2019 Exposure assessment method: employment history from personnel records	All cancers combined, incidence	SIR:			Age, calendar year	*Exposure assessment critique*: Satisfactory quality. Included firefighters with current or previous positions entailing active firefighting duties but no assessment of length of time in active firefighting positions, may include municipal and rural firefighters. *Strengths*: long length of follow-up (mean, 28 yr); near complete ascertainment of both cancer incidence and mortality; analyses by duration and timing of employment. *Limitations*: probable healthy-worker effect; no data on potential confounders apart from age, sex, and calendar time.
			Firefighters	845	1.15 (1.07–1.23)		
		All cancers combined, incidence	Year of first employment (SIR):				
			Pre-1950	304	1.29 (1.15–1.44)		
			1950–1969	284	1.08 (0.96–1.22)		
			1970 or after	257	1.08 (0.95–1.22)		
		All cancers combined, incidence	Time since first employment (SIR):				
			< 20 yr	66	1.09 (0.84–1.39)		
			20–39 yr	314	1.12 (1.00–1.25)		
			≥ 40 yr	465	1.18 (1.08–1.29)		
		All cancers combined, incidence	Duration of employment (SIR):				
			< 10 yr	74	1.01 (0.79–1.27)		
			10–19 yr	87	1.06 (0.85–1.31)		
			20–29 yr	217	1.15 (1.00–1.32)		
			≥ 30 yr	467	1.19 (1.09–1.30)		

Table S2.11 (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
Marjerrison et al. (2022b) Norway Enrolment, 1950–2019/follow-up, 1960–2018 Cohort	3881 male professional [career] firefighters (most were full-time) employed in positions entailing active firefighting at any of 15 fire departments between 1950 and 2019 Exposure assessment method: employment history from personnel records	All cancers combined, mortality	SMR:			Age, calendar year	*Exposure assessment critique*: Satisfactory quality. Included firefighters with current or previous positions entailing active firefighting duties but no assessment of length of time in active firefighting positions. May include municipal and rural firefighters. *Strengths*: long length of follow-up (mean, 28 yr); near complete ascertainment of both cancer incidence and mortality; analyses by duration and timing of employment. *Limitations*: probable healthy-worker effect; no data on potential confounders apart from age, sex, and calendar time.
			Firefighters	348	1.08 (0.97–1.20)		
		All cancers combined, incidence	Period of follow-up (SIR):				
			1984 or before	140	1.21 (1.02–1.43)		
			1985–1994	139	1.17 (0.98–1.38)		
			1995 or after	566	1.13 (1.04–1.23)		
		All cancers combined, mortality	Period of follow-up (SMR):				
			1984 or before	84	1.25 (1.00–1.55)		
			1985–1994	70	1.12 (0.87–1.41)		
			1995 or after	194	1.02 (0.88–1.17)		
		All cancers combined, incidence	Age at diagnosis (SIR):				
			≤ 49 yr	71	1.06 (0.83–1.34)		
			50–69 yr	374	1.09 (0.98–1.20)		
			≥ 70 yr	400	1.23 (1.11–1.36)		
		All cancers combined, mortality	Age at diagnosis (SMR):				
			≤ 49 yr	16	0.83 (0.47–1.34)		
			50–69 yr	123	0.96 (0.8–1.15)		
			≥ 70 yr	209	1.20 (1.05–1.38)		

Table S2.11 (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
Bigert et al. (2020) Sweden Enrolment 1960–1990/follow-up, 1961–2009 Cohort	8136; male firefighters identified from national censuses in 1960, 1970, 1980, and 1990. Exposure assessment method: questionnaire; ever employed and categorical duration of employment (years) as firefighter from census surveys	All cancers combined, incidence	SIR:			Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Unclear if individuals were active firefighter for whole employment. May include full-time, part-time, municipal, and rural firefighters. *Strengths*: near complete ascertainment of cancer incidence; long length of follow-up (mean, 28 yr); analyses stratified by calendar period of employment. *Limitations*: no data on job duties, employment type, or potential confounders (aside from age, sex, and calendar year); probable healthy-worker hire bias; potential non-differential misclassification of employment duration.
			Firefighters	1483	1.03 (0.97–1.09)		
		All cancers combined, incidence	Duration of employment (SIR):				
			1–9 yr	27	0.81 (0.53–1.18)		
			10–19 yr	349	1.01 (0.92–1.14)		
			20–29 yr	461	1.03 (0.94–1.13)		
			≥ 30 yr	646	1.04 (0.97–1.13)		
			Trend-test *P* value, 0.19				
		All cancers combined, incidence	Time period (SIR):				
			1961–1975	95	0.96 (0.78–1.18)		
			1976–1990	352	1.03 (0.93–1.15)		
			1991–2009	1036	1.04 (0.97–1.10)		

Table S2.11 (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
Kullberg et al. (2018) Stockholm, Sweden Enrolment, 1931–1983/follow-up, 1958–2012 Cohort	1080; men who worked ≥ 1 yr as a firefighter in Stockholm between 1931 and 1983. Exposure assessment method: ever employed and categorical duration of employment (years) as an urban [municipal] firefighter from annual enrolment records	All cancers combined, incidence	Follow-up period (SIR):			Birth year, calendar period	*Exposure assessment critique*: Satisfactory quality. Unclear if individuals were active firefighter for whole employment. Municipal firefighters. *Strengths*: long follow-up period; near complete ascertainment of cancer incidence; analyses of duration and era of employment. *Limitations*: no data on potential confounders (aside from age, sex, and calendar year); lack of exposure assessment based on job tasks or fire responses.
			Full: 1958–2012	265	0.81 (0.71–0.91)		
			Former: 1958–1986	130	1.03 (0.86–1.23)		
			Extended: 1987–2012	135	0.67 (0.56–0.79)		
		All cancers combined, incidence	Age at risk (SIR):				
			< 50 yr	6	0.40 (0.15–0.86)		
			50–64 yr	48	0.57 (0.42–0.76)		
			≥ 65 yr	211	0.92 (0.80–1.05)		
			Trend-test *P* value, < 0.01				
		All cancers combined, incidence	Duration of employment (SIR):				
			1–9 yr	18	0.47 (0.30–0.75)		
			10–19 yr	20	0.66 (0.42–1.02)		
			20–29 yr	64	0.98 (0.77–1.26)		
			≥ 30 yr	163	0.84 (0.72–0.98)		
			Trend-test *P* value, 0.03				
		All cancers combined, incidence	Period of first employment (SIR):				
			1902–1939	116	1.01 (0.84–1.21)		
			1940–1959	122	0.90 (0.75–1.07)		
			1960–1983	27	0.35 (0.24–0.51)		
			Trend-test *P* value, < 0.01				

Table S2.11 (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
Tornling et al. (1994) Stockholm, Sweden Enrolment, 1931–1983/follow-up, 1951–1986 (mortality), 1958–1986 (incidence) Cohort	1116 for mortality/1091 for incidence; male firefighters employed for ≥ 1 yr in the City of Stockholm between 1931 and 1983, identified from annual enrolment records Exposure assessment method: ever firefighter and duration (years) of firefighting employment from annual enrolment records; number of fires fought ascertained from exposure index developed from fire reports	All cancers combined, mortality	SMR:			Age, calendar period	*Exposure assessment critique*: Satisfactory/good quality. Enhanced exposure assessment (but based on 10% sample of reports) to differentiate exposure based on number of fires fought accounting for job position, station, and year of exposure. Municipal firefighters. *Strengths*: long follow-up period; near complete ascertainment of cancer incidence and mortality; assessed exposure to fire responses for some outcomes. *Limitations*: no data on potential confounders (aside from age, sex, and calendar year).
			Firefighters	93	1.02 (0.88–1.25)		
		All cancers combined, mortality	Age (SMR):				
			< 50 yr	3	0.57 (0.12–1.65)		
			50–64 yr	22	0.92 (0.58–1.40)		
			≥ 65 yr	68	1.09 (0.85–1.39)		
		All cancers combined, mortality	Duration of employment (SMR):				
			< 20 yr	9	0.85 (0.39–1.62)		
			20–30 yr	40	0.99 (0.71–1.35)		
			> 30 yr	44	1.09 (0.79–1.46)		
		All cancers combined, mortality	Latency (SMR):				
			< 30 yr	7	0.67 (0.27–1.39)		
			30–40 yr	26	1.85 (0.81–1.83)		
			> 40 yr	60	1.00 (0.76–1.29)		
		All cancers combined, mortality	No. of fires (SMR):				
			< 800	15	0.77 (0.43–1.27)		
			800–1000	24	0.89 (0.57–1.32)		
			> 1000	54	1.20 (0.90–1.57)		
		All cancers combined, incidence	SIR:				
			Firefighters	127	1.00 (0.83–1.19)		
		All cancers combined, incidence	Age (SIR):				
			< 50 yr	7	[0.74 (0.29–1.52)]		
			50–64 yr	30	0.85 (0.57–1.21)		
			≥ 65 yr	90	1.09 (0.88–1.34)		

Table S2.11 (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
Tornling et al. (1994) (cont.)		All cancers combined, incidence	Duration of employment (SIR):			Age, calendar period	
			< 20 yr	16	0.89 (0.51–1.45)		
			20–30 yr	41	0.79 (0.56–1.07)		
			> 30 yr	70	1.22 (0.95–1.54)		
		All cancers combined, incidence	Latency (SIR):				
			< 30 yr	14	0.79 (0.43–1.33)		
			30–40 yr	40	1.31 (0.94–1.78)		
			> 40 yr	73	0.92 (0.72–1.16)		
		All cancers combined, incidence	No. of fires (SIR):				
			< 800	27	0.91 (0.60–1.33)		
			800–1000	37	1.09 (0.77–1.51)		
			> 1000	63	0.99 (0.76–1.26)		

Table S2.11 (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
Petersen et al. (2018a) Denmark Enrolment, 1964–2004/follow-up, 1968–2014 Cohort	9061 male firefighters (full-time, part-time, and volunteer) identified from employer, trade union, and Danish Civil Registration System records, born 2 April 1928 or later, employed before age 60 yr and 31 December 2004, no cancer diagnosis before employment as a firefighter, and a job title/function indicating actual firefighting exposure Exposure assessment method: ever employed and categorical duration of employment (years), as well as employment type, job title/function, and work history, ascertained from civil registration, pension, employer personnel, and trade union membership records	All cancers combined excluding other skin (ICD-10, C44, C460), incidence	Reference group (SIR):			Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Includes part-time and full-time firefighters. Excluded those who did not actually fight fires. May include municipal and rural firefighters. *Strengths*: long period of follow-up; near-complete ascertainment of cancer incidence; use of three reference groups to evaluate healthy-worker bias; analyses by proxies of exposure including job task. *Limitations*: little information on potential confounders.
			Firefighters vs general population	1071	1.02 (0.96–1.09)		
			Firefighters vs sample of employees	1071	1.07 (1.01–1.14)		
			Firefighters vs military	1071	1.01 (0.95–1.07)		
		All cancers combined excluding other skin (ICD-10, C44, C460), incidence	Employment type (SIR):				
			Full-time	680	1.06 (0.99–1.15)		
			Part-time or volunteer	391	0.96 (0.87–1.06)		
		All cancers combined excluding other skin (ICD-10, C44, C460), incidence	Era of first employment (SIR):				
			Pre-1970	521	1.12 (1.02–1.22)		
			1970–1994	455	0.93 (0.85–1.02)		
			1995 or after	95	1.04 (0.84–1.27)		
		All cancers combined excluding other skin (ICD-10, C44, C460), incidence	Job function (SIR):				
			Regular	994	1.02 (0.96–1.08)		
			Specialized	77	1.12 (0.88–1.39)		
		All cancers combined excluding other skin (ICD-10, C44, C460), incidence	Age at first employment (SIR):				
			< 25 yr	527	1.12 (1.03–1.22)		
			25–34 yr	286	0.91 (0.81–1.03)		
			≥ 35 yr	213	0.95 (0.83–1.09)		

Table S2.11 (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
Petersen et al. (2018a) (cont.)		All cancers combined excluding other skin (ICD-10, C44, C460), incidence	Duration of employment (SIR):			Age, calendar period	
			< 1 yr	318	1.14 (1.02–1.27)		
			≥ 1 yr	753	0.98 (0.91–1.06)		
			≥ 10 yr	615	0.94 (0.87–1.02)		
			≥ 20 yr	447	0.91 (0.83–1.00)		
Petersen et al. (2018b) Denmark Enrolment, 1964–2014/follow-up, 1970–2014 Cohort	11 775 male firefighters (full-time, part-time, and volunteer) identified from employer, trade union, and Danish Civil Registration System records, born in 1928 or later, employed before age 60 yr and 31 December 2004, and a job title/function indicating actual firefighting exposure Exposure assessment method: ever employed and categorical duration of employment (years) as a firefighter ascertained from civil registration, pension, employer personnel, and trade union membership records	All cancers combined, mortality	Reference group (SMR):			Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Includes part-time and full-time firefighters. Excluded those who did not actually fight fires. May include municipal and rural firefighters. *Strengths*: long period of follow-up; use of military reference group to evaluate healthy-worker bias; analyses by duration of employment. *Limitations*: few data on potential confounders.
			Firefighters vs sample of employees	419	0.99 (0.89–1.09)		
			Firefighters vs military	419	1.05 (0.95–1.16)		
		All cancers combined, mortality	Employment type (SMR, military reference group):				
			Full-time	286	1.12 (1.00–1.26)		
			Part-time/volunteer	133	0.93 (0.77–1.1)		
		All cancers combined, mortality	Duration of employment, full-time firefighters (SMR, military reference group):				
			< 1 yr	138	1.18 (0.99–1.40)		
			≥ 1 yr	148	1.08 (0.91–1.26)		
			≥ 10 yr	124	1.01 (0.84–1.21)		
			≥ 20 yr	99	0.94 (0.76–1.15)		

Table S2.11 (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
Webber et al. (2021) New York City, USA 2001–2016 Cohort	10 786 FDNY, 8813 CFHS; FDNY and CFHS cohorts; male firefighters who were active on 11 September 2001; FDNY cohort included men who worked at the WTC site any time between 11 September 2001 and 25 July 2002; CFHS cohort included men who were actively employed on 11 September 2001 and assumed not to be working at the WTC site Exposure assessment method: presence at WTC site from employment records and duty rosters	All cancers combined including in situ bladder cancers, incidence	Group (SIR, US reference rates): CFHS firefighters FDNY WTC firefighters	 1002 915	 1.05 (0.98–1.12) 1.15 (1.08–1.23)	Age, calendar year, race/ethnicity	*Exposure assessment critique*: Satisfactory quality. Intensity of exposure at WTC captured but did not consider previous firefighter work. Qualitative assessment based on presence at the WTC site, exposures complex and probably unique to 9/11 disaster. Municipal firefighters. *Strengths*: ascertainment of cancer incidence; comparison of two firefighter cohorts to evaluate bias. *Limitations*: medical surveillance bias; young age of cohort; relatively short length of follow-up.
		All cancers combined including in situ bladder cancers, incidence	SIR (2-yr adjustment for potential surveillance bias): FDNY WTC firefighters	 NR	 1.09 (1.02–1.16)	Age, calendar year, race/ethnicity	
		All cancers combined including in situ bladder cancers, incidence	Group (RR): CFHS firefighters FDNY WTC firefighters	 1002 915	 1 1.13 (1.02–1.25)	Age on 11 September 2001, race/ethnicity	
		All cancers combined including in situ bladder cancers, incidence	Group RR (2-yr adjustment for potential surveillance bias): CFHS firefighters FDNY WTC firefighters	 NR NR	 1 1.07 (0.96–1.18)	Age, calendar year, race/ethnicity	

Table S2.11 (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
Zeig-Owens et al. (2011) New York City, USA Follow-up, 1 January 1996 to 31 December 2008 Cohort	9853 male FDNY firefighters who were employed for ≥ 18 mo, were active firefighters on 1 January 1996, with no prior cancer, and, if alive on 12 September 2001, also had known WTC exposure status Exposure assessment method: WTC exposed and unexposed firefighter from employment records and questionnaires	All cancers combined, incidence	WTC-exposure status (SIR):			Age, race, ethnic origin, calendar year	*Exposure assessment critique*: Satisfactory quality. Intensity of exposure at WTC captured but did not consider previous firefighter work. WTC exposure self-reported using three methods. WTC site exposures complex and probably unique to 9/11 disaster. *Strengths*: evaluation of medical surveillance bias. *Limitations*: healthy-worker hire bias; short length of follow-up; young age at end of follow-up; little information on potential confounders.
			Non-exposed	135	0.84 (0.71–0.99)		
			Exposed	263	1.10 (0.98–1.25)		
			SIR ratio (exposed vs non-exposed)	NR	1.32 (1.07–1.62)		
		All cancers combined, incidence	WTC-exposure status (SIR, 2-yr adjustment for potential surveillance bias):				
			Non-exposed	135	0.84 (0.71–0.99)		
			Exposed	242	1.02 (0.90–1.15)		
			SIR ratio (exposed vs non-exposed)	NR	1.21 (0.98–1.49)		
		All cancers combined, incidence	Sensitivity analysis (SIR ratio, exposed vs non-exposed):				
			Expanded cohort (including firefighters with first employment during follow-up)	NR	1.37 (1.12–1.68)		
			Multiple primaries included	NR	1.30 (1.06–1.59)		
			HR incident cancers (Cox regression)	NR	1.29 (1.04–1.60)		

Table S2.11 (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
Zeig-Owens et al. (2011) (cont.)			Late period of diagnosis (after 31 December 2004)	NR	1.34 (1.07–1.67)		
			Early period of diagnosis (before 1 January 2005)	NR	1.28 (0.99–1.67)		
			Date of diagnosis for 25 cases delayed beyond 2008	NR	1.19 (0.96–1.47)		

Table S2.11 (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
Pinkerton et al. (2020) San Francisco, Chicago, Philadelphia, USA Enrolment, 1950–2009/follow-up, 1950–2016 Cohort	29 992 municipal career firefighters in the CFHS cohort employed by the fire departments of San Francisco, Chicago, or Philadelphia for ≥ 1 day between 1950 and 2009; exposure–response analyses limited to 19 287 male firefighters of known race hired in 1950 or later and employed for ≥ 1 yr Exposure assessment method: ever employed as a firefighter, and number of exposed days, fire-runs, fire-hours reconstructed using job-exposure matrix based on job titles and assignments and departmental work history records and historical fire-run and fire-hour data	All cancers combined, mortality	Fire department (SMR):			Gender, race, age, calendar period	*Exposure assessment critique*: Good quality. Minimal bias in exposure assessment in internal analyses. Municipal firefighters. *Strengths*: long period of follow-up; exposure–response modelling for three metrics of exposure assessed using job-exposure matrices; adjustment for HWSE. *Limitations*: healthy-worker selection bias in external comparison analyses; little information on potential confounders.
			San Francisco	655	0.95 (0.88–1.02)		
			Chicago	1960	1.20 (1.15–1.26)		
			Philadelphia	1228	1.11 (1.04–1.17)		
			Overall	3843	1.12 (1.08–1.16)		
			Heterogeneity *P* value, < 0.01				
		All cancers combined, mortality	Race (SMR):			Gender, age, calendar period	
			White	3684	1.14 (1.10–1.18)		
			Non-White	159	0.79 (0.68–0.93)		
		All cancers combined, mortality	Age (SMR):			Gender, race, age, calendar period	
			< 65 yr	1237	0.96 (0.90–1.01)		
			≥ 65 yr	2606	1.22 (1.17–1.27)		
			Heterogeneity *P* value, < 0.01				
		All cancers combined, mortality	Exposed-days model (HR at 8700 exposed-days vs 2500 exposed-days, 10-yr lag):			Age, race, birthdate (within 5 yr), fire department	
			Loglinear without HWSE adjustment	1807	0.92 (0.83–1.01)		
			RCS without HWSE adjustment	1807	0.90 (0.80–1.02)		
			Fully adjusted loglinear	1807	1.14 (1.00–1.31)		
			Fully adjusted RCS	1807	1.11 (0.94–1.31)		

Table S2.11 (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
Pinkerton et al. (2020) (cont.)		All cancers combined, mortality	Fire-runs (Chicago and Philadelphia only) model (HR at 8800 runs vs 2100 runs, 10-yr lag):			Age, race, birthdate (within 5 yr), fire department	
			Loglinear without HWSE adjustment	1577	0.93 (0.86–1.00)		
			RCS without HWSE adjustment	1577	0.89 (0.82–0.98)		
			Fully adjusted loglinear	1577	1.02 (0.94–1.11)		
			Fully adjusted RCS	1577	1.00 (0.91–1.11)		
		All cancers combined, mortality	Fire-hours (Chicago only) model (HR at 2300 h vs 600 h, 10-yr lag)			Age, race, birthdate (within 5 yr), fire department	
			Loglinear without HWSE adjustment	1058	0.97 (0.87–1.08)		
			RCS without HWSE adjustment	1058	0.92 (0.81–1.05)		
			Fully adjusted loglinear	1058	1.08 (0.96–1.21)		
			Fully adjusted RCS	1058	1.04 (0.90–1.21)		
		All cancers combined, mortality	Time since first exposure in fire-runs (Chicago and Philadelphia only) fully adjusted loglinear model (HR for 8800 runs vs 2100 runs, 10-yr lag):			Age, race, birthdate (within 5 yr), fire department, employment duration	
			Lag to < 20 yr	NR	1.12 (0.88–1.42)		
			20 to < 30 yr	NR	1.02 (0.84–1.24)		
			≥ 30 yr	NR	0.98 (0.86–1.12)		
			LRT *P* value, 0.61				

Table S2.11 (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
Daniels et al. (2015) San Francisco, Chicago, Philadelphia, USA Enrolment, 1950–2009/follow-up, 1950–2009 (mortality), 1985–2009 (incidence) Cohort	19 309; all male career firefighters in the CFHS cohort of known race who were on active duty ≥ 1 day from 1950 through 2009 in the fire departments of Chicago, Philadelphia, or San Francisco with ≥ 1 yr of employment Exposure assessment method: number of exposed days, fire-runs, fire-hours reconstructed using job-exposure matrix based on job titles and assignments and departmental work history records and historical fire-run and fire-hour data	All cancers combined, incidence	Exposed-days model (HR, RCS model, 10-yr lag):			Age, race, fire department, birth cohort	*Exposure assessment critique*: Good quality. Minimal bias in exposure assessment in internal analyses. Municipal firefighters. *Strengths*: long period of follow-up; exposure–response modelling for three metrics of exposure assessed using job-exposure matrices. *Limitations*: little information on potential confounders.
			8700 days vs 2500 days	2609	0.96 (0.87–1.05)		
		All cancers combined, incidence	Fire-runs (Chicago and Philadelphia only) model (HR, loglinear model, 10-year lag):			Age, race, fire department, birth cohort	
			8800 runs vs 2100 runs	2197	1.01 (0.95–1.08)		
		All cancers combined, incidence	Fire-hours (Chicago only) model (HR, loglinear model, 10-yr lag):			Age, race, birth cohort	
			2300 h vs 600 h	1395	1.01 (0.92–1.12)		
Daniels et al. (2014) San Francisco, Chicago, Philadelphia, USA Enrolment, 1950–2009/follow-up, 1950–2009 (mortality), 1985–2009 (incidence) Cohort	29 993 (24 453 for incidence analyses) male and female career firefighters in the CFHS cohort employed for ≥ 1 day in Chicago, San Francisco, or Philadelphia fire departments between 1950 and 2009 Exposure assessment method: ever employed and categorical duration of employment (years) from employment records	All cancers combined, incidence	SIR:			Gender, race, age, calendar period	*Exposure assessment critique*: Satisfactory quality. Minimum exposure is 1 day of work as a municipal firefighter. *Strengths*: long period of follow-up; ascertained incidence outcomes; included female firefighters. *Limitations*: healthy-worker hire bias in external comparisons; little information on potential confounders.
			All primary cancers	4461	1.09 (1.06–1.12)		
			First primary cancer	3890	1.09 (1.06–1.12)		
		All cancers combined, incidence	SIR, women:			Race, age, calendar period	
			All primary cancers	40	1.24 (0.89–1.69)		
		All cancers combined, incidence	Race, men (SIR, all cancers):			Age, calendar period	
			Caucasian [White]	4181	1.10 (1.07–1.13)		
			Other	240	0.92 (0.81–1.05)		

Table S2.11 (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
Demers et al. (1994) Seattle and Tacoma, Washington, USA Enrolment, 1944–1979/follow-up, 1974–1989 Cohort	2447 male firefighters employed for ≥ 1 yr between 1944 and 1979, alive as of 1 January 1974 and known to be a resident of one of 13 counties in the catchment area of the cancer registry for ≥ 1 mo; reference group included 1878 local male police officers Exposure assessment method: ever employed for ≥ 1 yr, and categorical duration of employment (years) in direct firefighting positions from employment records	All cancers combined, incidence All cancers combined, incidence All cancers combined, incidence All cancers combined, incidence	SIR (local county rates): Firefighters IDR: Local police Firefighters Duration of exposed employment (SIR, local county rates): < 10 yr 10–19 yr 20–29 yr ≥ 30 yr Years since first employment (SIR, local county rates): < 20 yr 20–29 yr ≥ 30 yr	 224 114 224 32 36 133 23 10 40 174	 1.1 (0.9–1.2) 1 1.0 (0.8–1.3) 1.1 (0.8–1.6) 1.1 (0.8–1.5) 1.0 (0.9–1.2) 1.0 (0.7–1.6) 0.7 (0.3–1.4) 1.3 (0.9–1.7) 1.0 (0.9–1.2)	Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Duration (years) involved in direct firefighting (surrogate for fire smoke) was not measured equally in the two study populations. Municipal firefighters. *Strengths*: use of two comparison groups, including comparison with police officers to limit healthy-worker bias. *Limitations*: little information on potential confounders.
Demers et al. (1992a) Seattle and Tacoma, Washington, and Portland, Oregon, USA Enrolment, 1944–1979/follow-up, 1944–1989 Cohort	4401; male firefighters employed for ≥ 1 yr between 1944 and 1979 in Seattle, Tacoma, or Portland; reference group included 3676 local police officers Exposure assessment method: ever employed for ≥ 1 yr, and categorical duration (years) of exposure to fire combat from employment records	All cancers combined, mortality All cancers combined, mortality	SMR: Firefighters IDR: Local police Firefighters	 291 169 291	 0.95 (0.85–1.07) 1 0.97 (0.80–1.17)	Age, calendar period	*Exposure assessment critique*: Satisfactory/good quality. Duration of years involved in fire combat (surrogate for fire smoke) was not measured equally in the three municipal firefighter populations. *Strengths*: use of two comparison groups, including comparison with police officers to limit healthy-worker bias. *Limitations*: little information on potential confounders; ascertained mortality outcomes only.

Table S2.11 (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
Vena & Fiedler (1987) Buffalo, New York, USA 1950–1979 Cohort	1867 White male career firefighters employed by the City of Buffalo for ≥ 5 yr, with ≥ 1 year as a firefighter Exposure assessment method: ever-employment, timing, and duration of employment from employment records	All cancers combined, mortality	SMR:			Age, calendar period	*Exposure assessment critique*: Minimal quality. Only assessed ever-employment and duration of employment as a municipal firefighter. *Strengths*: long length of follow-up. *Limitations*: healthy-worker hire bias; little information on potential confounders or exposure to firefighting activities.
			Firefighters	102	1.09 (0.89–1.32)		
		All cancers combined, mortality	Years worked as a firefighter (SMR):				
			1–9 yr	5	[0.89 (0.3–2.0)]		
			10–19 yr	7	[0.66 (0.3–1.3)]		
			20–29 yr	24	[0.87 (0.6–1.3)]		
			30–39 yr	34	[0.95 (0.7–1.3)]		
			≥ 40 yr	32	[2.20 (1.5–3.1)]		
		All cancers combined, mortality	Latency (SMR):			Age and calendar period, age, calendar period	
			< 20 yr	10	[0.81 (0.4–1.4)]		
			20–29 yr	14	[0.68 (0.4–1.1)]		
			30–39 yr	29	[0.98 (0.7–1.4)]		
			40–49 yr	33	[1.39 (1.0–1.9)]		
			≥ 50 yr	16	[2.11 (1.2–3.3)]		
Feuer & Rosenman (1986) New Jersey, USA 1974–1980 Cohort	263 deceased White male firefighters in the New Jersey Police and Firemen Retirement System (firefighters vested with ≥ 10 years of service, or firefighters who died while on payroll regardless of employment duration); one reference group included 567 White male police deaths Exposure assessment method: ever employed, and categorical duration of employment (years), as a career firefighter from retirement system records	All cancers combined, mortality	Reference population (PMR):			Age, race	*Exposure assessment critique*: Satisfactory quality. Assessment provides duration of employment categories. May include municipal and rural firefighters. *Strengths*: comparison with other uniformed service occupation. *Limitations*: PMR study design lacks event-free follow-up time; short observation period; little information on potential confounders.
			Firefighters vs US White men	67	[1.15 (0.90–1.45)]		
			Firefighters vs NJ White men	67	[1.00 (0.78–1.26)]		
			Firefighters vs White male NJ police	67	[1.07 (0.83–1.35)]		
		All cancers combined, mortality	Duration of employment (PMR):				
			≤ 20 yr	15	[0.91 (0.53–1.47)]		
			20–25 yr	18	[0.95 (0.58–1.47)]		
			> 25 yr	34	[1.09 (0.77–1.51)]		
		All cancers combined, mortality	Latency (PMR):				
			≤ 22 yr	15	[0.84 (0.49–1.35)]		
			22–27 yr	22	[1.10 (0.71–1.64)]		
			> 27 yr	30	[1.03 (0.71–1.45)]		

Table S2.11 (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
Aronson et al. (1994) Toronto, Canada 1950–1989 Cohort	5414 male firefighters employed for ≥ 6 mo at one of six fire departments in Metropolitan Toronto any time between 1950 and 1989 Exposure assessment method: ever employed and categorical duration of employment (years) as municipal firefighter from employment records	All cancers combined, mortality	SMR:			Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Unclear if individuals were active firefighters for whole employment. Probably municipal firefighters. *Strengths*: long period of follow-up; analysis of employment duration. *Limitations*: healthy-worker hire bias; little information on confounders or exposure; ascertained mortality outcomes only.
			Any employment	199	1.05 (0.91–1.20)		
		All cancers combined, mortality	Years since first exposure (SMR):				
			< 20 yr	28	1.21 (0.81–1.76)		
			20–29 yr	36	0.94 (0.66–1.31)		
			≥ 30 yr	135	1.06 (0.89–1.26)		
		All cancers combined, mortality	Years of employment (SMR):				
			< 15 yr	36	1.38 (0.96–1.91)		
			15–29 yr	52	0.89 (0.66–1.16)		
			≥ 30 yr	101	0.98 (0.80–1.19)		
		All cancers combined, mortality	Age (SMR):				
			< 60 yr	87	1.08 (0.86–1.33)		
			≥ 60 yr	112	1.04 (0.86–1.25)		
Guidotti (1993) Edmonton and Calgary, province of Alberta, Canada 1927–1987 Cohort	3328; all firefighters employed between 1927 and 1987 by either of the fire departments of Edmonton or Calgary Exposure assessment method: ever employed and categorical duration of employment (years) from employment records; exposure index of years weighted by exposure opportunity	All cancers combined, mortality	SMR:			Age, calendar period	*Exposure assessment critique*: Good quality. Good approach to differentiate exposure between ranks. Urban [municipal] firefighters. *Strengths*: attempt to improve the exposure surrogate "duration of employment" by weighting with the potential for exposure; long observation period. *Limitations*: relatively small cohort; no data on potential confounders.
			Any employment	92	1.27 (1.02–1.55)		
		All cancers combined, mortality	Year of cohort entry (SMR):				
			Pre-1920	30	[1.62 (1.11–2.28)]		
			1920–29	5	[0.91 (0.33–2.02)]		
			1930–39	5	[0.75 (0.27–1.66)]		
			1940–49	22	[1.46 (0.94–2.18)]		
			1950–59	1	[1.17 (0.06–5.77)]		
			1960–69	9	[1.55 (0.76–2.85)]		
			1970–79	1	[0.43 (0.02–2.10)]		
		All cancers combined, mortality	Latency (SMR):				
			< 20 yr	13	[0.98 (0.55–1.64)]		
			20–29 yr	17	[1.05 (0.63–1.65)]		
			30–39 yr	25	[1.22 (0.80–1.77)]		
			40–49 yr	23	[1.76 (1.15–2.61)]		
			≥ 50 yr	14	[1.44 (0.82–2.36)]		

Table S2.11 (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
Guidotti (1993) (cont.)		All cancers combined, mortality	Exposure index (SMR):			Age, calendar period	
			0	7	[1.67 (0.73–3.31)]		
			> 0, < 1	13	[1.96 (1.09–3.27)]		
			1–9	17	[1.44 (0.86–2.25)]		
			≥ 10	62	[1.14 (0.88–1.46)]		
		All cancers combined, mortality	Latency, exposure index = 0 (SMR):				
			< 20 yr	2	[0.98 (0.16–3.22)]		
			20–29 yr	3	[3.37 (0.86–9.17)]		
			30–39 yr	1	[1.32 (0.07–6.46)]		
			40–49 yr	1	[3.05 (0.15–15.0)]		
			≥ 50 yr	0	0 (NR)		
		All cancers combined, mortality	Latency, exposure index > 0, < 1 (SMR):				
			< 20 yr	4	[1.41 (0.45–3.40)]		
			20–29 yr	4	[2.48 (0.79–5.99)]		
			30–39 yr	4	[2.59 (0.83–6.27)]		
			40–49 yr	1	[2.20 (0.11–11.0)]		
			≥ 50 yr	0	0 (NR)		
		All cancers combined, mortality	Latency, exposure index 1–9 (SMR):				
			< 20 yr	3	[0.67 (0.17–1.84)]		
			20–29 yr	5	[2.23 (0.82–4.95)]		
			30–39 yr	5	[1.90 (0.70–4.21)]		
			40–49 yr	2	[1.53 (0.26–5.04)]		
			≥ 50 yr	2	[1.65 (0.28–5.46)]		
		All cancers combined, mortality	Latency, exposure index ≥ 10 (SMR):				
			< 20 yr	6	[1.01 (0.41–2.10)]		
			20–29 yr	8	[0.65 (0.30–1.24)]		
			30–39 yr	16	[0.98 (0.58–1.55)]		
			40–49 yr	20	[1.77 (1.11–2.69)]		
			≥ 50 yr	12	[1.44 (0.78–2.45)]		

Table S2.11 (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
Glass et al. (2019) Australia Follow-up for death, 1980–2011; for cancer, 1982–2012 Cohort	39 644 female firefighters, both paid [career] (1682) and volunteer (37 962), from nine fire agencies in Australia Exposure assessment method: ever career or volunteer firefighter, ever attended an incident, tertiles of cumulative number of incidents and type of incidents attended from personnel records	All cancers combined, mortality	SMR:			Age, calendar period	*Exposure assessment critique*: Good quality. Enhanced exposure assessment to differentiate exposure based on number of incidents for volunteer firefighters. Included specific incident types, but early exposure was extrapolated from more recent data. Volunteers mainly rural. *Strengths*: study of female firefighters; includes predominantly rural firefighters; ascertained exposure to number and type of incidents. *Limitations*: short length of follow-up; young age at end of follow-up; probable healthy-worker bias; little information on confounders.
			Paid [career] firefighters	10	0.83 (0.44–1.54)		
			Volunteer firefighters	268	0.75 (0.66–0.84)		
			Volunteer firefighters who attended incidents	118	0.88 (0.73–1.05)		
		All cancers combined, mortality	No. of incidents, all volunteers (RMR [equivalent to mortality rate ratio]):				
			Zero incidents	124	1		
			Tertile 1	33	1.07 (0.73–1.58)		
			Tertile 2	45	1.25 (0.89–1.76)		
			Tertile 3	40	1.41 (0.98–2.02)		
			Trend-test *P* value, 0.24				
		All cancers combined, mortality	No. of fire incidents, all volunteers (RMR):				
			Zero incidents	132	1		
			Tertile 1	36	1.22 (0.84–1.77)		
			Tertile 2	34	1.09 (0.75–1.60)		
			Tertile 3	40	1.45 (1.02–2.08)		
			Trend-test *P* value, 0.45				
		All cancers combined, mortality	No. of structure fire incidents, all volunteers (RMR):				
			Zero incidents	200	1		
			Tertile 1	5	0.39 (0.16–0.95)		
			Tertile 2	20	1.24 (0.78–1.96)		
			Tertile 3	17	1.17 (0.71–1.92)		
			Trend-test *P* value, 0.05				

Table S2.11 (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
Glass et al. (2019) (cont.)		All cancers combined, mortality	No. of landscape fire incidents, all volunteers (RMR):			Age, calendar period	
			Zero incidents	142	1		
			Tertile 1	24	1.00 (0.64–1.54)		
			Tertile 2	34	1.14 (0.78–1.65)		
			Tertile 3	42	1.52 (1.07–2.15)		
			Trend-test *P* value, 0.08				
		All cancers combined, mortality	No. of vehicle fire incidents, all volunteers (RMR):				
			Zero incidents	207	1		
			Tertile 1	8	0.93 (0.46–1.89)		
			Tertile 2	11	0.99 (0.54–1.82)		
			Tertile 3	16	1.52 (0.91–2.53)		
			Trend-test *P* value, 0.20				
		All cancers combined, incidence	SIR:				
			Paid firefighters	28	1.15 (0.80–1.67)		
			Volunteer firefighters	1027	0.97 (0.91–1.03)		
			Volunteer firefighters who attended incidents	421	0.97 (0.88–1.07)		
		All cancers combined, incidence	No. of incidents, all volunteers (RIR) [equivalent to rate ratios]:				
			Zero incidents	418	1		
			Tertile 1	119	0.98 (0.80–1.20)		
			Tertile 2	145	1.03 (0.85–1.25)		
			Tertile 3	138	1.14 (0.93–1.38)		
			Trend-test *P* value, 0.19				

Table S2.11 (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
Glass et al. (2019) (cont.)		All cancers combined, incidence	No. of fire incidents, all volunteers (RIR):			Age, calendar period	
			Zero incidents	445	1		
			Tertile 1	122	1.03 (0.85–1.27)		
			Tertile 2	122	1.01 (0.83–1.24)		
			Tertile 3	131	1.14 (0.94–1.39)		
			Trend-test *P* value, 0.39				
		All cancers combined, incidence	No. of structure fire incidents, all volunteers (RIR):				
			Zero incidents	653	1		
			Tertile 1	40	0.74 (0.54–1.02)		
			Tertile 2	64	1.02 (0.79–1.32)		
			Tertile 3	63	1.04 (0.80–1.35)		
			Trend-test *P* value, 0.14				
		All cancers combined, incidence	No. of landscape fire incidents, all volunteers (RIR):				
			Zero incidents	478	1		
			Tertile 1	103	1.06 (0.85–1.31)		
			Tertile 2	109	0.95 (0.77–1.18)		
			Tertile 3	130	1.18 (0.97–1.43)		
			Trend-test *P* value, 0.38				
		All cancers combined, incidence	No. of vehicle fire incidents, all volunteers (RIR):				
			Zero incidents	682	1		
			Tertile 1	40	1.04 (0.76–1.44)		
			Tertile 2	42	0.96 (0.70–1.31)		
			Tertile 3	56	1.29 (0.98–1.69)		
			Trend-test *P* value, 0.28				

Table S2.11 (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
Glass et al. (2017) Australia Enrolment, date varied by agency (1998–2000)/ follow-up through 30 November 2011 (mortality) and 31 December 2010 (cancer incidence) Cohort	163 094; all male volunteer firefighters from five fire agencies enrolled on or after the date on which the agency's roll was complete and who had ever held an active firefighting role Exposure assessment method: ever volunteer firefighter, categorical volunteer duration (years) and era from service records; ever volunteer firefighter who attended an incident, tertiles of cumulative emergency incidents from contemporary incident data	All cancers combined, mortality	SMR:			Age, calendar period	*Exposure assessment critique*: Good quality. Enhanced exposure assessment to differentiate exposure based on number of incidents. Included specific incident types, but early exposure was extrapolated from more recent data. Firefighters from rural or peri-urban areas. *Strengths*: includes predominantly rural firefighters; ascertained exposure to number and type of incidents. *Limitations*: short length of follow-up; young age at end of follow-up; probable healthy-worker bias; little information on confounders.
			All volunteers	1900	0.59 (0.57–0.62)		
			Volunteers who attended incidents	1166	0.59 (0.55–0.62)		
		All cancers combined, mortality	Era of first service (SMR):				
			Pre-1970	620	0.59 (0.54–0.64)		
			1970–1994	648	0.56 (0.51–0.60)		
			1995 or after	632	0.64 (0.59–0.69)		
		All cancers combined, mortality	Duration of service (SMR):				
			> 3 mo to 10 yr	582	0.67 (0.61–0.72)		
			10–20 yr	342	0.60 (0.54–0.67)		
			≥ 20 yr	949	0.55 (0.52–0.59)		
		All cancers combined, mortality	Duration of service (RMR):				
			> 3 mo to 10 yr	582	1		
			10–20 yr	342	0.91 (0.80–1.04)		
			≥ 20 yr	949	0.85 (0.76–0.94)		
			Trend-test *P* value, < 0.01				
		All cancers combined, mortality	No. of incidents attended by volunteers (RMR):				
			Baseline	1082	1		
			Group 1	58	1.23 (0.95–1.61)		
			Group 2	26	1.16 (0.79–1.72)		
		All cancers combined, mortality	No. of fire incidents attended by volunteers (RMR):				
			Baseline	1084	1		
			Group 2	60	1.21 (0.95–1.56)		
			Group 3	22	1.11 (0.73–1.69)		
		All cancers combined, mortality	No. of structure fire incidents attended by volunteers (RMR):				
			Baseline	1108	1		
			Group 2	38	1.38 (1.00–1.91)		
			Group 3	20	1.37 (0.88–2.13)		

Table S2.11 (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
Glass et al. (2017) (cont.)		All cancers combined, mortality	No. of landscape fire incidents attended by volunteers (RMR):			Age, calendar period	
			Baseline	926	1		
			Group 2	171	1.08 (0.91–1.27)		
			Group 3	69	1.15 (0.90–1.47)		
		All cancers combined, mortality	No. of vehicle fire incidents attended by volunteers (RMR):				
			Baseline	1081	1		
			Group 2	63	1.29 (1.00–1.66)		
			Group 3	22	1.19 (0.78–1.81)		
		All cancers combined, incidence	SIR:				
			All volunteers	7057	0.86 (0.84–0.88)		
			Volunteers who attended incidents	4491	0.85 (0.83–0.88)		
		All cancers combined, incidence	Duration of service, all volunteers (RIR):				
			> 3 mo to 10 yr	2206	1		
			10–20 yr	1315	1.00 (0.93–1.07)		
			≥ 20 yr	3452	0.99 (0.93–1.04)		
			Trend-test *P* value, 0.67				
		All cancers combined, incidence	Duration of service, volunteers who attended incidents (RIR):				
			> 3 mo to 10 yr	1029	1		
			10–20 yr	827	1.09 (1.00–1.20)		
			≥ 20 yr	2682	1.06 (0.98–1.14)		
			Trend-test *P* value, 0.25				
		All cancers combined, incidence	No. of incidents attended by volunteers (RIR):				
			Baseline	4184	1		
			Group 2	210	1.09 (0.95–1.26)		
			Group 3	97	1.05 (0.86–1.28)		

Table S2.11 (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
Glass et al. (2017) (cont.)		All cancers combined, incidence	No. of fire incidents attended by volunteers (RIR):			Age, calendar period	
			Baseline	4191	1		
			Group 2	217	1.09 (0.95–1.25)		
			Group 3	83	1.02 (0.82–1.37)		
		All cancers combined, incidence	No. of structure fire incidents attended by volunteers (RIR):				
			Baseline	4283	1		
			Group 2	142	1.20 (1.01–1.42)		
			Group 3	66	1.08 (0.84–1.37)		
		All cancers combined, incidence	No. of landscape fire incidents attended by volunteers (RIR):				
			Baseline	3566	1		
			Group 2	681	1.07 (0.98–1.16)		
			Group 3	244	1.05 (0.92–1.19)		
		All cancers combined, incidence	No. of vehicle fire incidents attended by volunteers (RIR):				
			Baseline	4191	1		
			Group 2	218	1.08 (0.94–1.24)		
			Group 3	82	1.06 (0.85–1.31)		

Table S2.11 (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
Glass et al. (2016a) Australia Enrolment, 1976–2003/follow-up, 1976–2011 (mortality), 1982–2010 (incidence, except two states, 2009) Cohort	30 057 full-time (17 394) or part-time (12 663) paid male firefighters employed at one of eight Australian fire agencies for ≥ 3 mo from start of personnel records (1976–2003, depending on agency) Exposure assessment method: employed as a part- or full-time firefighter for ≥ 3 mo, categorical employment duration (years) and era from employment records; tertiles of cumulative emergency incidents and type of incident attended from contemporary incident data	All cancers combined, mortality	Firefighter status (SMR):			Age, calendar period	*Exposure assessment critique*: Good quality. Enhanced exposure assessment to differentiate exposure based on number of incidents, including specific incident types. Included specific incident types but early exposure extrapolated from more recent data. Municipal firefighters. *Strengths*: internal analysis by exposure to number and type of incidents; ascertained cancer incidence. *Limitations*: healthy-worker hire bias; short length of follow-up; young age at end of follow-up; little information on potential confounders.
			Full-time	329	0.81 (0.72–0.90)		
			Part-time	124	0.84 (0.70–1.00)		
			All	453	0.81 (0.74–0.89)		
		All cancers combined, incidence	Firefighter status (SIR):				
			Full-time	1208	1.08 (1.02–1.14)		
			Part-time	485	1.11 (1.01–1.21)		
			All	1693	1.09 (1.03–1.14)		
		All cancers combined, incidence	Duration of employment, full-time firefighters (RIR) [equivalent to rate ratios]:				
			> 3 mo to 10 yr	138	1		
			10–20 yr	196	1.09 (0.87–1.37)		
			≥ 20 yr	866	1.08 (0.87–1.34)		
			Trend-test *P* value, 0.58				
		All cancers combined, incidence	Duration of employment, part-time firefighters (RIR):				
			> 3 mo to 10 yr		1		
			10–20 yr	114	1.07 (0.82–1.40)		
			≥ 20 yr	223	0.98 (0.74–1.29)		
			Trend-test *P* value, 0.84				
		All cancers combined, incidence	Duration of employment (RIR):				
			> 3 mo to 10 yr	282	1		
			10–20 yr	310	1.09 (0.92–1.29)		
			≥ 20 yr	1089	1.05 (0.89–1.23)		
			Trend-test *P* value, 0.74				
		All cancers combined, incidence	No. of incidents attended by full-time firefighters (RIR):				
			Tertile 1	102	1		
			Tertile 2	126	1.29 (0.99–1.68)		
			Tertile 3	180	1.13 (0.88–1.45)		
			Trend-test *P* value, 0.44				

Table S2.11 (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
Glass et al. (2016a) (cont.)		All cancers combined, incidence	No. of fire incidents attended by full-time firefighters (RIR):			Age, calendar period	
			Tertile 1	101	1		
			Tertile 2	110	1.23 (0.94–1.62)		
			Tertile 3	197	1.21 (0.95–1.55)		
			Trend-test *P* value, 0.15				
		All cancers combined, incidence	No. of structure fire incidents attended by full-time firefighters (RIR):				
			Tertile 1	110	1		
			Tertile 2	116	1.16 (0.89–1.51)		
			Tertile 3	182	1.06 (0.83–1.35)		
			Trend-test *P* value, 0.70				
		All cancers combined, incidence	No. of landscape fire incidents attended by full-time firefighters (RIR):				
			Tertile 1	96	1		
			Tertile 2	142	1.54 (1.18–1.99)		
			Tertile 3	170	1.18 (0.92–1.53)		
			Trend-test *P* value, 0.35				
		All cancers combined, incidence	No. of vehicle fire incidents attended by full-time firefighters (RIR):				
			Tertile 1	98	1		
			Tertile 2	122	1.48 (1.13–1.93)		
			Tertile 3	188	1.34 (1.04–1.71)		
			Trend-test *P* value, 0.04				

Table S2.11 (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
Glass et al. (2016b) Victoria, Australia Enrolment, 1971–1999/follow-up, 1980–2011 (mortality), 1982–2012 (incidence) Cohort	614; all male (611) and female (3) employed and volunteer Country Fire Authority trainers and a group of paid [career] Country Fire Authority firefighters who trained at the Fiskville site from 1971 to 1999; all analyses limited to men as no deaths or cancers were observed among women Exposure assessment method: employed or volunteer firefighter trainers and career firefighters who trained at training facility for any period of time from human resources records, categorized into risk of low, medium, and high chronic exposure to smoke and other agents based on job assignment	All cancers combined, mortality	Risk of chronic exposure (SMR):			Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Incorporated categorical level of exposure into assessment for each type of firefighter. Volunteers mainly rural, career firefighters were municipal. *Strengths*: included firefighter instructors with high potential exposure to smoke and other hazardous agents; assessed exposure based on job assignment. *Limitations*: low number of cases; young age at end of follow-up.
			Low	1	0.29 (0.01–1.64)		
			Medium	9	0.87 (0.40–1.65)		
			–Paid	4	0.89 (0.24–2.27)		
			–Volunteer	5	0.85 (0.28–1.99)		
			–Volunteer with Fiskville start date	0	0 (NR)		
			–With Fiskville human resources start date	4	0.66 (0.18–1.69)		
			High	6	1.47 (0.54–3.19)		
			–With Fiskville human resources start date	6	1.70 (0.62–3.70)		
		All cancers combined, incidence	Risk of chronic exposure (SIR):				
			Low	6	0.40 (0.15–0.87)		
			Medium	38	1.13 (0.80–1.55)		
			–Paid	16	1.26 (0.72–2.05)		
			–Volunteer	22	1.05 (0.66–1.59)		
			–Volunteer with Fiskville start date	17	0.86 (0.50–1.37)		
			–With Fiskville human resources start date	23	1.31 (0.83–1.97)		
			High	25	1.85 (1.20–2.73)		
			–With Fiskville human resources start date	24	2.06 (1.32–3.06)		

Table S2.11 (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
Bates et al. (2001) New Zealand Enrolment, 1977 through June 1995/ follow-up, 1977–1995 (mortality), 1977–1996 (incidence) Cohort	4305; all male (4221) and female (84) firefighters (paid [career] and volunteer) employed as a career firefighter for ≥ 1 yr and who also worked as a career firefighter for ≥ 1 day between 1977 and 1995; all analyses limited to men due to small numbers of women Exposure assessment method: ever employed and categorical duration of employment (years) from employment records	All cancers combined, incidence	Follow-up period (SIR):			Age, calendar period	*Exposure assessment critique*: Satisfactory quality. Heterogeneity of direct firefighter exposure within job classification. May include urban [municipal] and rural firefighters. *Strengths*: ascertained both incidence and mortality outcomes. *Limitations*: little information on confounders; significant loss to follow-up.
			1977–1996	118	0.95 (0.8–1.1)		
			1990–1996	72	1.01 (0.8–1.3)		
		All cancers combined, incidence	Period of diagnosis (SIR):				
			1977–1981	8	0.62 (0.3–1.2)		
			1982–1986	20	0.96 (0.6–1.5)		
			1987–1991	35	1.06 (0.7–1.5)		
			1992–1996	55	0.96 (0.7–1.3)		
		All cancers combined, incidence	Duration of paid service (SIR):				
			0–10 yr	28	1.03 (0.7–1.5)		
			11–20 yr	31	1.38 (0.9–2.0)		
			> 20 yr	39	1.19 (0.9–1.6)		
			Trend-test *P* value, 0.68				
		All cancers combined, incidence	Duration of paid and volunteer service (SIR):				
			0–10 yr	14	0.93 (0.5–1.6)		
			11–20 yr	33	1.75 (1.2–2.5)		
			> 20 yr	51	1.04 (0.8–1.4)		
			Trend-test *P* value, 0.60				
		All cancers combined, incidence	SMR:				
			Firefighters vs male New Zealand population	42	0.81 (0.6–1.1)		

Table S2.11 (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
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	All cancers combined, incidence	SIR:			Age, calendar period	*Exposure assessment critique*: Minimal quality. Only ever urban [municipal] firefighter exposure. *Strengths*: ascertained cancer incidence. *Limitations*: little information on potential confounders; lack of exposure or employment duration analyses.
			Firefighters vs Victoria male rates	50	1.13 (0.84–1.48)		
		All cancers combined, incidence	Attained age (SIR):				
			< 65 yr	29	0.84 (0.56–1.20)		
			≥ 65 yr	21	2.14 (1.32–2.37)		
		All cancers combined, incidence	Time since first employment (SIR):				
			< 15 yr	6	1.18 (0.43–2.56)		
			15–29 yr	14	1.40 (0.77–2.35)		
			≥ 30 yr	30	1.02 (0.69–1.46)		
		All cancers combined, incidence	Duration of employment (SIR):				
			< 15 yr	3	0.49 (0.10–1.43)		
			15–29 yr	20	1.39 (0.85–2.15)		
			≥ 30 yr	27	1.13 (0.74–1.64)		

9/11, World Trade Center disaster, 11 September 2001; BMI, body mass index; CFHS, Career Firefighter Health Study; CI, confidence interval; FDNY, Fire Department of the City of New York; HR, hazard ratio; HWSE, healthy-worker survivor effect; ICD, International Classification of Diseases; IDR, incidence density ratio; LRT, likelihood ratio test; mo, month; NJ, New Jersey; NR, not reported; PMR, proportionate mortality ratio; RCS, restricted cubic splines; RIR, relative incidence ratio; RMR, relative mortality ratio [equivalent to mortality rate ratio]; RR, rate ratio; SIR, standardized incidence ratio; SMR, standardized mortality ratio; SRR, standardized rate ratio; US, United States; vs, versus; WTC, World Trade Center; yr, year.

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