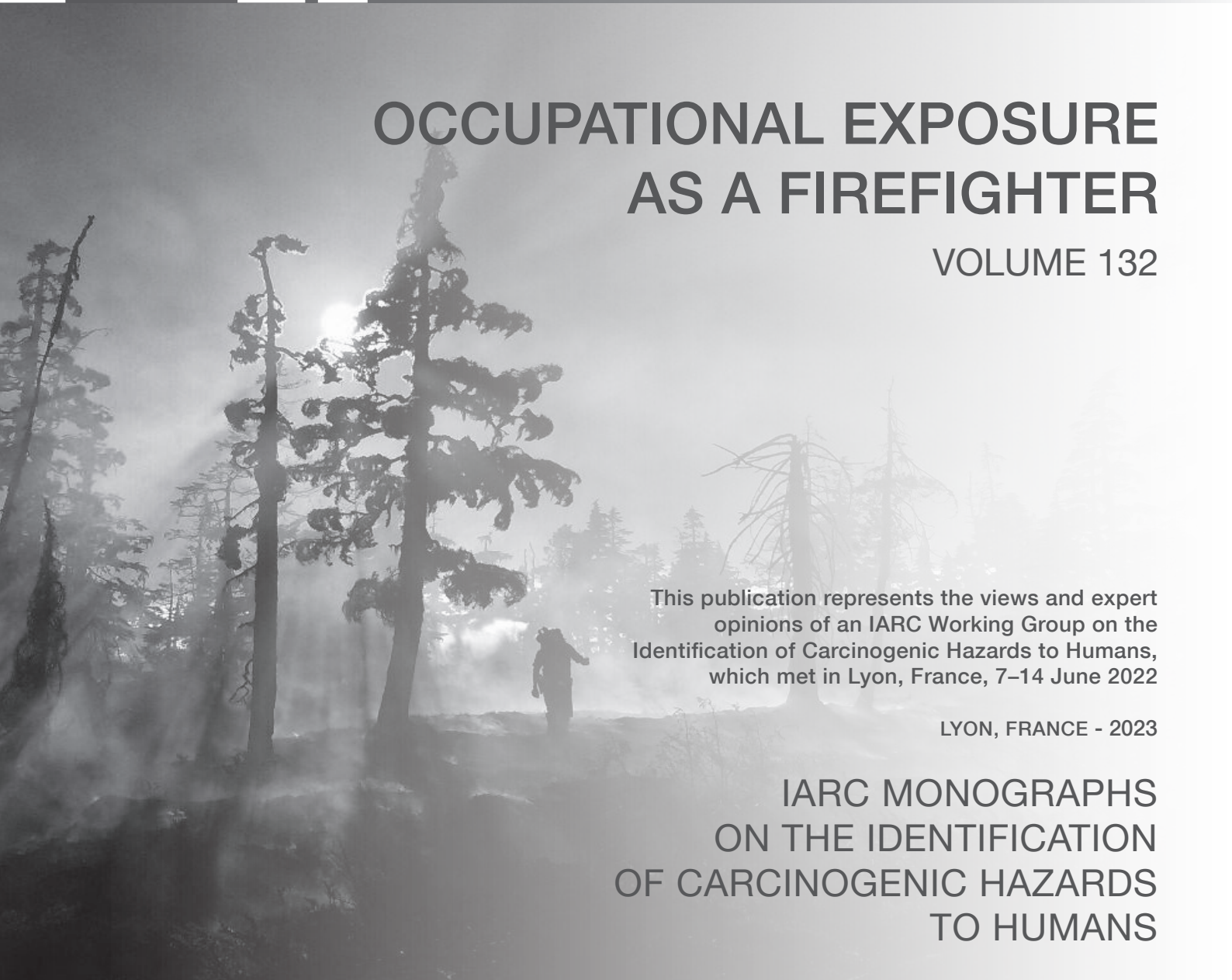


# OCCUPATIONAL EXPOSURE AS A FIREFIGHTER

VOLUME 132



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OF CARCINOGENIC HAZARDS  
TO HUMANS

**Table S1.28 Exposure assessment review and critique for epidemiological studies on cancer and occupational exposure as a firefighter**

| Reference and outcome   | Study design        | Study location and exposure period                                 | Source of exposure data  | Exposure definition  | Concerns noted on exposure classification   | Derived exposure metrics   | Timing of exposure relative to outcome | Co-exposures to carcinogens | Differential exposure misclassification |
|---|---------------------|--|--|--|---|--|--|-----------------------------|---|
| <i>Cohort studies</i>   |                     |  |  |  |   |  |  |                             |   |
| Sritharan et al. (2022)<br>Cancer incidence (various sites)               | Cohort – 13 642 ff  | Ontario, USA, 1960s to 2020  | Accepted lost-time workers' compensation injury & disease claims data held by Workplace Safety & Insurance Board | Firefighting occupation coded from job recorded in claims data               | Job at time of claim only   | Employed as ff at time of claim  | Predates                               | No data                     | Unlikely                                |
| Marjerrison et al. (2022)<br>Cancer incidence (various sites)             | Cohort – 3881 ff    | Norway, 15/22 fire departments, 1950–2018                          | Personnel records  | Active male ffs (chimney sweeps, fire inspectors, office personnel excluded) | Assumes no change in job, e.g. becoming a fire inspector  | Employment duration (< 10, 10–19, 20–29, ≥ 30 yr)  | Predates                               | No data                     | Unlikely                                |
| Webber et al. (2021)<br>Cancer incidence (all cancers and 6 common sites) | Cohort – 19 599 ff  | New York city, Philadelphia, Chicago, San Francisco USA, 2001–2002 | Employment records, duty rosters   | Men working as ff at WTC site between 11 Sept. 2001 and 25 July 2002         |   | Working as ff at WTC site between 11 Sept. 2001 and 25 July 2002. Five ordinal categories of exposure intensity based on time of arrival at WTC site | Predates                               | Smoking                     | Unlikely                                |
| Bigert et al. (2020)<br>Cancer incidence (various sites)                  | Cohort 8136 ff      | Sweden, 1960–1990  | Years of employment as ff inferred from census   | Males, self-reported occupation as ff for > 50% regular working hours        | May not have been full-time ff. 10 yr between census so duration inexact. Assumes all jobs were active ff. Rural and urban [municipal] ff. combined | Employment duration (1–9, 10–19, 20–29, 30+ yr)  | Predates                               | No data                     | Unlikely                                |
| Colbeth et al. (2020)<br>Thyroid cancer incidence                         | Cohort – 14 987 ffs | New York City USA, 2001–2002                                       | Employment records and duty rosters  | Men working as ff at WTC site from 11 Sept. 2001 to 25 July 2002             | Highly variable exposures to complex mixture of toxicants   | Presence/ absence at WTC site. Five ordinal categories of exposure intensity based on time of arrival at WTC site                                    | Predates                               | Smoking                     | Unlikely                                |

**Table S1.28 Exposure assessment review and critique for epidemiological studies on cancer and occupational exposure as a firefighter**

| Reference and outcome   | Study design       | Study location and exposure period                                 | Source of exposure data  | Exposure definition   | Concerns noted on exposure classification   | Derived exposure metrics  | Timing of exposure relative to outcome | Co-exposures to carcinogens | Differential exposure misclassification   |
|---|--------------------|--|--|---|---|---|--|-----------------------------|---|
| Pinkerton et al. (2020)<br>Cancer mortality (various sites)         | Cohort – 29 992 ff | Three US cities, (San Francisco, Chicago, Philadelphia), 1950–2009 | Employment records and job exposure matrix   | Employed as ff  | Exposed days were not necessarily on active fires   | Hours working as active ff with potential exposure (exposed-days), hours responding to fires (fire hours), number of fire runs  | Predates                               | No data                     | Unlikely  |
| Zhao et al. (2020)<br>Cancer mortality (various sites)              | Cohort – 27 365 ff | Spain, 2001  | 2001 National Census employment report   | Self-reported working as ff in the week before the census         | Self-reported job title on census, exposure measure only one point in time. No information on work type   | Ever employed as ff   | Predates                               | No data                     | Unlikely  |
| Glass et al. (2019)<br>Cancer incidence (various sites)             | Cohort – 39 644 ff | Australia, pre-1970–2011, varied by agency                         | Employment and service records, and incident history records from nine fire agencies | Ever a paid or volunteer female ff engaged in active firefighting | Incident data was not available for 5710 volunteer ffs (removed from analysis), or for some ffs' full history (estimated using mean incidents per year for years with data) | Ever employed or volunteered, ever attended incidents, duration (> 3 mo to < 10 yr, 10–20, 20+ yr), era of first service, tertiles of cumulative incidents (all incidents, all fire incidents, structure fires, landscape fires, vehicle fires) | Predates                               | No data                     | Incident estimates were needed for older firefighters and may have underestimated incidents attended in early years |
| Ugelvig Petersen et al. (2018a)<br>Cancer incidence (various sites) | Cohort – 9061 ff   | Denmark, <1970 – 2014  | Employment records, pension fund register  | Employed as full-time or part-time male ff                        |   | Employment duration (< 1, ≥ 1, ≥ 10, ≥ 20 yr), employment type (full time, other) and function (regular, specialized)   | Predates                               | No data                     | Unlikely  |
| Kullberg et al. (2018)<br>Cancer incidence (various sites)          | Cohort – 1080 ff   | Stockholm Sweden, 1931–1983  | Fire station annual enrolment records  | Men employed as ff at least 1 yr                                  |   | Employment duration (1–9, 10–19, 20–29, 30+ yr)   | Unclear                                | No data                     | Unlikely  |

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|--|---------------------|--|---|--|--|--|--|-----------------------------|---|
| Ugelvig Petersen et al. (2018b)<br>Cancer mortality (various sites)              | Cohort – 11 775 ff  | Denmark, <1970 – 2014                        | Employment records, pension fund register   | Men employed as ff   |  | Employment duration (< 1, ≥ 1, ≥ 10 and ≥ 20 yr), full time vs part time/volunteer   | Predates                               | No data                     | Unlikely  |
| Harris et al. (2018)<br>Cancer incidence (various sites)                         | Cohort – 4535 ff    | Canada, 1991 census day                      | National census employment report as ff or fire chief/senior ff officer             | Self-reported working as ff as current or longest held job in 1991 or 1990 | Current or longest held job may have changed between censuses  | Employed as ff in 1991 or 1990   | Predates                               | No data                     | Unlikely  |
| Glass et al. (2017)<br>Cancer incidence (various sites) and all cancer mortality | Cohort – 163 094 ff | Australia, pre-1970 to 2010 varied by agency | Service records and incident history records from five fire agencies                | Ever an active volunteer male ff   | For some ffs' full volunteer history was estimated using mean incidents per year for years with data | Ever volunteered, ever attended incidents, volunteer duration (> 3 mo to <10 yr, 10–20, 20+ yr), era of first enrolment (pre-1970, 1970–1994, post-1995), tertiles of cumulative incidents attended (all incidents, all fire incidents, structure fires, landscape fires, vehicle fires) | Predates                               | No data                     | Incident estimates were needed for older firefighters and may have underestimated incidents attended in early years |
| Glass et al. (2016a)<br>Cancer incidence (various sites) Cancer death (overall)  | Cohort – 611        | Victoria, Australia, 1971–1999               | Country Fire Authority employee and volunteer human resource records, self-reported | Employed and volunteer male ff trainers, and paid ff trainees              | Missing start dates high in some groups provided by individual ffs                                   | Low, medium, or high risk of chronic exposure  | Predates                               | No data                     | Self-reported employment dates for some in high and medium groups   |

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|--|---|--|---|---|---|---|--|-----------------------------|--|
| Glass et al. (2016b)<br>Cancer incidence (various sites) Cancer mortality (all malignancies) | Cohort – 30 057 ff                                  | Australia, pre-1970–2010 varied by agency            | Employment and incident history records from eight fire agencies      | Part- and full-time paid male ffs who worked at least 3 mo in active ff role  | Some ffs’ full employment history started before incident collection (estimated using mean incidents per year for years with data available)  | Ever employed as male active ff, employment duration (> 3 mo to < 10 yr, 10–20, 20+ yr), era of first employment (pre-1970, 1970–1994, post-1995), tertiles of cumulative incidents attended (all incidents, all fire incidents, structure fires, landscape fires, vehicle fires) | Predates                               | No data                     | Older ffs may have experienced more incidents in early years |
| Moir et al. (2016)<br>Cancer incidence (various sites)                                       | Cohort – 19 677 ff, including 11 457 WTC-exposed ff | New York city USA, 2001–2002                         | Employment records, self-report                                       | White male working as ff at WTC site from 9/11/2001 to 7/25/2002  | Highly variable exposures to complex chemicals at WTC   | Presence/absence at WTC site  | Predates                               | No data                     | Unlikely   |
| Daniels et al. (2015)<br>Cancer incidence and mortality (various sites)                      | Cohort – 19 309 ff                                  | San Francisco, Chicago, Philadelphia, USA, 1950–2009 | Employment records and job exposure matrix                            | Male employed as ff   | Exposed days were not necessarily on active fires   | Hours working as active ff, hours responding to fires, cumulative career exposed days, fire runs, fire hours  | Predates                               | No data                     | Unlikely   |
| Ahn & Jeong (2015)<br>Cancer mortality (various sites)                                       | Cohort – 33 442 ff                                  | Republic of Korea, 1980–2007                         | Korean National Emergency Management Agency (NEMA) employment records | Employment by NEMA for at least one month as a male first- or second-line suppression firefighting duties (e.g. work on fire truck, division chief) | Some “non-ffs” positions may share exposures with “ffs” including shift work and fire smoke (e.g. fire investigators). Type of work (full- versus part-time, busyness) not considered | Ever employed as ff, employment duration categories (< 10, 10–20, > 20 yr)  | Predates                               | No data                     | Unlikely   |

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|---|--------------------|---|--|---|--|---|--|-----------------------------|---|
| Amadeo et al. (2015)<br>Cancer mortality (various sites)                | Cohort – 10 829 ff | France, 1979  | 89 of 96 Departmental Fire and Rescue Service employment records                         | Men employed as professional ff on 1 January 1979   | Exposure measure only at entry in 1979   | Ever employed as ff   | Predates                               | No data                     | Unlikely                                |
| Daniels et al. (2014)<br>Cancer incidence and mortality (various sites) | Cohort – 29 993 ff | San Francisco, Chicago, Philadelphia, USA 1950–2009 | Employment records and previous study data   | Duration of employment as ff for at least one day between 1 January 1950 and 31 December 2009 | Minimum duration criteria for exposure (1 day) is low. Exposed days were not necessarily on active fires   | Ever employed as ff, employment duration (0–< 10, 10–< 20, 20–< 30, 30+ yr)   | Predates                               | No data                     | Unlikely                                |
| Pukkala et al. (2014)<br>Cancer incidence (various sites)               | Cohort – 16 422 ff | Nordic Countries, 1960–1990                         | One or more censuses between 1960–1990, in Denmark, Finland, Iceland, Norway and Sweden  | Self-reported employment as a male ff on census   | Exposure measure only at entry at time of census. No consideration for differences in types of firefighting  | Employed as ff  | Predates                               | No data                     | Unlikely                                |
| Ahn et al. (2012)<br>Cancer incidence (various sites)                   | Cohort – 29 438 ff | Republic of Korea, 1980 – 2007                      | Employment records   | Duration of employment as male emergency responder with ff job title                          | Misclassification from crude definition of exposure  | Duration of employment as ff < 10 vs ≥ 10 yr  | Predates                               | Smoking, alcohol            | Unlikely                                |
| Zeig-Owens et al. (2011)<br>Cancer incidence (various sites)            | Cohort – 9853 ff   | New York, USA, 2001–2002                            | Employment records and self-reported WTC exposure status by questionnaire, phone or mail | Men working as NY ff for at least 18 mo   | Self-reported WTC exposure status measured in three different ways. Limited information on how exposure was assessed by questionnaire, phone, mail | Working at least one day as ff at WTC site between 11 Sept. 2001 and 25 July 2002. Five ordinal categories of exposure intensity based on time of arrival at WTC site | Predates                               | Smoking                     | Unlikely                                |

**Table S1.28 Exposure assessment review and critique for epidemiological studies on cancer and occupational exposure as a firefighter**

| Reference and outcome   | Study design       | Study location and exposure period | Source of exposure data  | Exposure definition  | Concerns noted on exposure classification   | Derived exposure metrics                         | Timing of exposure relative to outcome | Co-exposures to carcinogens | Differential exposure misclassification |
|---|--------------------|------------------------------------|--|--|---|--|--|-----------------------------|---|
| Ma et al. (2006)<br>Cancer incidence (various sites)                  | Cohort – 36 813 ff | Florida, USA, 1972–1999            | Florida State Fire Marshal’s Office professional certification records | Working as ff with professional certification between 1972 and 1999                                      | Assumed all ffs were exposed until exit of the study. Certification began in 1972 therefore ffs who were first certified included ffs that may have worked for long periods, but cancer registration did not start until 1981 | Ever employed as ff                              | Predates                               | No data                     | Unlikely                                |
| Ma et al. (2005)<br>Cancer mortality (various sites)                  | Cohort – 39 455 ff | Florida, USA, 1972–1999            | Florida State Fire Marshal’s Office professional certification records | Working as ff with professional certification between 1972 and 1999                                      | Assumed all ffs were exposed until exit of the study. Certification began in 1972 therefore ffs who were first certified included ffs that may have worked for long periods   | Ever employed as ff                              | Predates                               | No data                     | Unlikely                                |
| Bates et al. (2001)<br>Cancer incidence and mortality (various sites) | Cohort – 4305 ff   | New Zealand, 1977–1995             | Employment records   | Employed as paid ff $\geq 1$ yr  | Misclassification from crude definition of exposure   | Employment duration as ff (0–10, 11–20, > 20 yr) | Predates                               | No data                     | Unlikely                                |
| Deschamps et al. (1995)<br>Cancer mortality (various sites)           | Cohort – 830 ff    | Paris France, $\leq 1972$ –1991    | Employment records   | Men employed as ff working on assignments involving active fire combat duty with 5 yr or more of service | Employed as ff  | Employed as ff                                   | Predates by at least 5 yr              | No data                     | Unlikely                                |
| Aronson et al. (1994)<br>Cancer mortality (various sites)             | Cohort – 5414 ff   | Toronto Canada, 1950–1989          | Employment records   | Men employed as ff with 5 yr or more of service  | 97% active ffs, 3% other work but were previously ff  | Employment duration (< 15, 15–29, 30+ yr)        | Predates                               | No data                     | Unlikely                                |

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|--|-------------------------|---------------------------------------|--|---|---|---|--|-----------------------------|---|
| Tornling et al. (1994)<br>Cancer mortality and incidence (various sites) | Cohort – 1116 ff        | Stockholm, Sweden, 1931–1983          | Annual enrolment and fire event records from 15 fire stations  | Men with duration of employment as ff or ff officer (min. 1 yr) between 1931 and 1983. Also exposure index using number of fires fought | Exposure index (# fires) derived from 10% sample of fire reports accounting for station, ff versus officers, and year. 10% sample may not be accurate | Employment duration (< 20, 20–30, > 30 yr), number of fires fought (< 800, 800–1000, > 1000 fires), number of fires wearing SCBA  | Predates                               | No data                     | Unlikely  |
| Demers et al. (1994)<br>Cancer incidence (various sites)                 | Cohort – 2447 ff        | Seattle and Tacoma, USA 1944–1979     | Employment records   | Men with duration of employment as ff (min. 1 yr) between 1944 and 1979   | Exposure measurement of fire combat could be assessed only for Seattle ffs  | Employment duration in direct fire combat (< 10, 10–19, 20–29, 30+ yr)  | Predates                               | No data                     | Unlikely  |
| Burnett et al. (1994)<br>Cancer mortality (various sites)                | Cohort – 5744 ff        | 27 US states, Before 1984–1990        | Death certificate occupation information   | Usual occupation of ff on death certificate   | Misclassification of ff from death certificate coding   | Usual occupation as ff  | Predates                               | No data                     | Over-reporting, or more accurate reporting of ff possible for certain causes of death |
| Guidotti (1993)<br>Cancer mortality (various sites)                      | Pooled Cohort – 3328 ff | Edmonton & Calgary, Canada, 1927–1987 | Years as ff from Fire Department employment records. Intensity weighting derived from interviews with groups of ff | Duration of employment as ff  | Weighting likely to result in some misclassification but better than duration alone   | Employment duration (< 1, 1–9, 10–19, 20–29, 30–39, 40+ yr), exposure opportunity (EO) = job weighted by time likely close to fires, EO groups 0, > 0 < 1, 1–4, 5–9, 10–14, 15–19, 20–24, 25–29, 30–35, 35+ | Predates                               | No data                     | Unlikely  |
| Giles et al. (1993)<br>Cancer incidence (various sites)                  | Cohort – 2865 ff        | Victoria, Australia, 1917–1989        | Employment records   | Men employed as active ff   |   | Employed as ff  | Predates                               | No data                     | Unlikely  |



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|--|------------------|--|---|---|--|--|--|-----------------------------|---|
| Demers et al. (1992a)<br>Cancer mortality (various sites)    | Cohort – 4546 ff | Seattle, Tacoma, Portland, USA 1944–1979 | Employment records                                      | Men employed as a ff for at least 1 yr between 1944 and 1979  | Exposure measurement of fire combat assessed differently in Seattle and Portland vs. Tacoma  | Ever employed as ff, fire combat years (surrogate for fire smoke) = total employment years minus years in administration, fire prevention, or support services (< 10, 10–19, 20–29, ≥ 30 yr) | Predates                               | No data                     | Difference in the method to calculate duration of fire combat between cities          |
| Grimes et al. (1991)<br>Cancer mortality (various sites)     | Cohort – 205 ff  | Honolulu City and County, USA, pre 1988  | State of Hawaii death certificates used in PMR analysis | Men with occupation as ff from death certificates   | No information on type of ff   | Ever employed as ff  | Predates                               | No data                     | Over-reporting, or more accurate reporting of ff possible for certain causes of death |
| Vena & Fiedler (1987)<br>Cancer mortality (various sites)    | Cohort – 1867 ff | Buffalo USA, 1950–1979                   | Employment records                                      | Men employed at least 1 yr as ff and at least 5 yr as municipal employee  |  | Employed as ff   | Predates                               | No data                     | Unlikely  |
| Feuer & Rosenman (1986)<br>Cancer mortality (various sites)  | Cohort – 263 ff  | New Jersey, USA, pre 1980                | Police and Firemen Retirement System (PFRS) records     | Paid ffs who either: (1) had at least 10 yr of employment, (2) died while on payroll, or (3) disabled from work related issue | Does not capture uninjured/deceased ffs with less than 10 yr of employment. Does not distinguish type of firefighting role or full-versus part-time status | Ever employed as ff, employment duration (≤ 20, 20–25, ≥ 25 yr)  | Predates                               | No data                     | Unlikely  |
| Eliopoulos et al. (1984)<br>Cancer mortality (various sites) | Cohort – 990 ff  | Western Australia, 1939–1978             | Western Australian Fire Brigade employment records      | Men employed as full-time ff between 1 October 1939 and 31 December 1978  | No indication if job position or full-time status changed after enrolment  | Ever employed as ff, employment duration (< 1, 1–9, 10–19, 20–29, ≥ 30 yr)   | Predates                               | No data                     | Unlikely  |

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|---|--|--|---|--|--|--|---|---|--|
| Musk et al. (1978)<br>Cancer mortality (various sites)                    | Cohort – 5655 ff   | Boston USA, 1915–1975                  | Employment records  | Men employed as ff with $\geq 3$ yr service  |  | Employment as ff                             | Predates by $\geq 3$ yr                     | No data   | Unlikely   |
| Mastromatteo (1959)<br>Cancer mortality                                   | Cohort – 1832 ff   | Toronto Ontario Canada, 1918–1953      | Superannuation and benefit fund registry  | Employed as ff   | Grouped pensioners and active employed ffs together  | Employment as ff                             | Predates                                    | No data   | Unlikely   |
| Lee et al. (2020)<br>Cancer incidence (various sites)                     | Case–control – 3928 ff cases   | Florida USA, 1972–2012                 | Employment and professional certification records   | Employed or certified as ff [suppression or fire prevention] between 1981 and 2014   | Mixed ffs and fire prevention, unclear if certified ffs included in the study may never work as a ff   | Ever employed as a ff                        | Predates                                    | No data   | Unlikely   |
| Langevin et al. (2020)<br>Head and neck squamous cell carcinoma incidence | Case–control – Hospital identified 11 ff of 718 cases                | Greater Boston area USA, pre 1999–2011 | Self-administered questionnaire   | Men employed as ff with job duties that involved firefighting. Fire inspectors or administrators excluded  | Years of work from self-report   | Ever employed as ff, duration employed as ff | Predates. History collected after diagnosis | Ever/never smoker and pack-years, alcohol, none, $\leq 2$ , 2+ drinks/day | Case and control job history evaluation likely not blinded. Possible recall bias                   |
| McClure et al. (2021)<br>Cancer incidence (various sites)                 | Case–control – 3760 ff employment data, 1831 ff cancer registry only | Florida USA, 1972–2014                 | Two methods: (1) cancer registry records, (2) ff employment and certification records linked to cancer registry records | Two definitions: (1) employment as ff (longest held job), (2) employed or certified as ff. Ff included ff, first-line supervisors of ff and prevention workers, fire inspectors, emergency medical technicians, paramedics | (1) Large grouping of jobs, included paramedics (authors tested for the effect of this)<br><br>(2) Mixed ffs & fire prevention, unclear if certified ffs included in the study ever worked as a ff | Ever employed as ff                          | Predates                                    | No data   | Underreporting of occupation in cancer registry, (1/2) mixed ff jobs and no indication of duration |

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|--|---|---|---|--|---|--|---|---|---|
| Muegge et al. (2018)<br>Cancer mortality (various sites) | Case–control – 2818 cases               | Indiana USA, Pre-1985 to 2013   | Industry & occupation coding of death certificates for usual occupation | Usual occupation as ff from death certificate  |   | Usual occupation as ff   | Predates                                    | No data   | Over-reporting, or more accurate reporting of ff possible for certain causes of death |
| Bigert et al. (2016)<br>Lung cancer incidence            | 14 pooled case–control studies 84 cases | Europe, China, Canada, New Zealand. Data collection period varied with study, pre 1985–2010 | Self-reported lifetime work histories                                   | Men employed as ff > 6 mo including fire suppression, prevention, aircraft accidents and other ffs | Heterogeneity of exposure among types of ff, rural vs urban [municipal] ff. Detailed tasks and length of employment not available | Ever employed as ff, duration employed (< 6, 6–21, 22–32, >32 yr)                | Predates. History collected after diagnosis | Smoking: never, former, current. Pack years. Years since quitting. Another occupation with increased lung cancer risk | Unlikely  |
| Tsai et al. (2015)<br>Cancer incidence (various sites)   | Case–control – 3996 ff cases            | California USA, 1988–2007   | Self-reported lifetime work histories from cancer registry              | Men with longest held occupation as ff including fire suppression, prevention, and inspection      | Mixing different types of ff  | Ever employed as ff  | Predates. History collected after diagnosis | No data   | Recall bias possible  |
| Kang et al. (2008)<br>Cancer incidence (various sites)   | Case–control – 2125 ff cases            | Massachusetts USA, pre-1987 to 2003   | Self-reported to cancer registry  | Men with longest held occupation (at least 1 yr) as ff engaged in suppression                      | Incorporates both current and retired ffs, no information on type of ff work. Occupation self-reported                            | Longest held occupation (at least 1 yr) as ff engaged in suppression             | Predates. History collected after diagnosis | Smoking   | Unlikely  |
| Stang et al. (2003)<br>Testicular cancer incidence       | Case–control – 4/269 cases were ff      | 5 regions Germany, 1971–1997  | Self-reported lifetime work histories (face to face interview)          | Employment as ff   |   | Ever employed as ff, ≥ 10 yr employment duration, ≥5 yr before date of diagnosis | Predates. History collected after diagnosis | No data   | Recall bias possible  |

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|--|--|---|---|--|---|--|---|---------------------------------|---|
| Ma et al. (1998)<br>Cancer mortality (various sites)   | Case–control – 1883 cases  | 24 US states, pre-1984 to 1993              | Industry & occupation coding of death certificates for usual occupation   | Men with usual occupation as ff from death certificate   |   | Usual occupation as ff   | Predates.                                   | No data                         | Over-reporting, or more accurate reporting of ff possible for certain causes of death |
| Muscat & Wynder (1995)<br>Laryngeal cancer incidence   | Case–control – 2/235 cases were ff                               | New York USA, pre-1985 to 1992              | Self-reported job and exposure histories for the six longest held jobs (for at least 1 yr)                          | Men employed as ff, also exposure to diesel exhaust, and diesel fume jobs                                    | Limited information, interviewer not blinded. Unclear if interview coder was blinded to case status as well | Ever employed as ff, duration of exposure  | Predates. History collected after diagnosis | Smoking and alcohol consumption | Recall bias, interviewers not blinded   |
| Sama et al. (1990)<br>Cancer incidence (various sites) | Case–control – 315 case ff                                       | Massachusetts USA, pre-1982 to 1986         | Self-reported job history and secondary sources (hospital and union records, death certificates, funeral directors) | Men with usual occupation as ff or fire chief. Jobs listed as fireman were confirmed using secondary sources | Exposure measured only one point in time. Self-reported “usual” job may not be accurate                     | Usual occupation as ff   | Predates. History collected after diagnosis | Cigarette smoking               | Unlikely  |
| <i>Other, e.g. case reports</i>                        |  |   |   |  |   |  |   |                                 |   |
| Geiger et al. (2020)<br>Renal cancer                   | Case series – 4 ff   | Pacific north-western USA, pre-2014 to 2019 | Clinic electronic health-care records, online survey for length of firefighting                                     | Duration of employment as ff   | Not applicable  | Employment duration as ff  | Predates                                    | Smoking                         | Not applicable  |
| Landgren et al. (2018)<br>Multiple myeloma             | Case series – 16 ff with multiple myeloma, 781 ff MGUS screening | New York USA 2001–2002                      | WTC Health Program health services records. Self-administered questionnaire   | Men working as ff at WTC site from 9/11/2001 to 7/25/2002  | Highly variable exposures to complex chemicals  | Presence/absence at WTC site, arrival date 2001: morning of 11 Sept., afternoon of 11 Sept., 12 Sept., 13–24 Sept., 25 Sept. to 24 July 2002 | Predates                                    | No data                         | Not applicable  |

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| Reference and outcome                                  | Study design                | Study location and exposure period | Source of exposure data   | Exposure definition  | Concerns noted on exposure classification  | Derived exposure metrics   | Timing of exposure relative to outcome | Co-exposures to carcinogens                               | Differential exposure misclassification |
|--|-----------------------------|------------------------------------|---------------------------|--|--|--|--|---|---|
| Antoniv et al. (2017)<br>Laryngeal cancer              | Cancer cases from Chernobyl | Chernobyl Ukraine, 1986            | Not specified             | Men working as ff/cleanup workers, exposed to ionizing radiation from the Chernobyl nuclear accident                       | The Russian term “liquidators”, often translated as “clean-up workers”, has been translated to “firefighters” by the authors/journal | None specified   | Predates $\geq 5$ yr                   | No data   | Unclear                                 |
| Sugi et al. (2013)<br>Eosinophilic granuloma           | Case report                 | Los Angeles, USA                   | Assumed medical interview | Employed as ff   |  | None specified   | Unclear                                | No data   | NA                                      |
| Cormack (2013)<br>Peritoneal mesothelioma              | Case report                 | Middlesbrough, United Kingdom      | Assumed medical interview | Employed as ff before retirement   |  | None specified   | Unclear                                | Smoking history 40 pack years, probable asbestos exposure | NA                                      |
| Schrey et al. (2013)<br>Extramedullary myeloid sarcoma | Case report                 | Turku, Finland, pre-2013           | Assumed medical interview | Employed as ff   |  | None specified   | Predates                               | Chemotherapy for AML 5 yr earlier                         | NA                                      |
| Wolfe et al. (2012)<br>Squamous cell carcinoma         | Case report                 | Florida, USA, 1976–2004            | Assumed medical interview | Wildlands ff for 28 yr (15-h days), estimated direct daily radiant heat exposure was 1 h ( $\leq 4$ ft from the fire line) |  | Employment duration as ff, h/day noted “protective equipment included Nomex pants and shirt without insulation, leather gloves and work boots, and hard hat” | Predates                               | UV and radiant heat from camping                          | NA                                      |
| Cucchi (2003)<br>Mesothelioma of pericardium           | Case report                 | Sondrio, Italy, pre-2003           | Assumed medical interview | Employed as ff   |  | None specified   | Unclear                                | Asbestos  | NA                                      |

**Table S1.28 Exposure assessment review and critique for epidemiological studies on cancer and occupational exposure as a firefighter**

| Reference and outcome                    | Study design   | Study location and exposure period | Source of exposure data                                 | Exposure definition  | Concerns noted on exposure classification | Derived exposure metrics  | Timing of exposure relative to outcome      | Co-exposures to carcinogens | Differential exposure misclassification |
|--|----------------|------------------------------------|---|--|---|---------------------------|---|-----------------------------|---|
| Bates & Lane (1995)<br>Testicular cancer | Cluster - 4 ff | Wellington New Zealand, 1984–1989  | Employed as ff from occupational history from interview | Employed as urban [municipal] ff, volunteer and fulltime, fighting fires, inhaling smoke |   | Employment duration as ff | Predates. History collected after diagnosis | No data                     | NA                                      |

ff(s), firefighter(s); MGUS, monoclonal gammopathy of undetermined significance; NA, not applicable; NECSS, Enhanced Cancer Surveillance System; NZSCO, New Zealand Standard Classification of Occupations; SCBA, self-contained breathing apparatus; WTC, World Trade Center; yr, year.

[] Reviewers' interpretation/comment.

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