IIAC

THE INDUSTRIAL INJURIES ADVISORY COUNCIL

POSITION PAPER 47

Firefighters and cancer

gov.uk/iiac

This publication is available at: www.gov.uk/iiac.

Any enquiries regarding this publication should be sent to us at iiac@dwp.gov.uk.

INDUSTRIAL INJURIES ADVISORY COUNCIL

Dr L RUSHTON, OBE, BA, MSc, PhD, CStat, Hon FFOM (Chair)

Professor R AGIUS, MD, DM, FRCP, FRCPE, FFOM

Professor K BURTON, OBE PhD Hon FFOM

Professor J CHERRIE, CFFOH

Mr K CORKAN, BA

Ms L FRANCOIS, MA, LLM

Dr M HENDERSON, MSc, PhD, MRCP, MRCPsych, HonFFOM

Dr J HOYLE, MD, FRCP, MRCPE

Dr S KHAN, BMedSci, FFOM, FRCGP, FRCP, DM

Dr I LAWSON, MB, BS, FFOM, FRCP, FRSPH

Ms K MITCHELL, LLB

Professor N PEARCE, BSc, DipSci, DipORS, PhD, DSc

Mr D RUSSELL, BSc (Hons), MSc, CMIOSH

Mr D SHEARS, BA(Hons)

Dr C STENTON, BSc, MB, BAO, FRCP, FFOM, FFOM.RCPI

Professor K WALKER-BONE, BM, FRCP, PhD, Hon FFOM

Dr A WHITE, BSc (Hons), PhD, CMIOSH, AIEMA

HSE Observer:	L DARNTON
IIAC Secretariat:	
Secretary:	Mr S WHITNEY
Scientific Advisor:	Mr I CHETLAND
Administrative Secretary:	Ms C HEGARTY

Firefighters and cancer

Summary

The House of Commons Environmental Audit Committee (EAC) in their report 'Toxic Chemicals in Everyday Life' raised concerns about the exposure of firefighters and clean-up workers to toxic chemicals from the Grenfell fire. Following this a formal request was made to the Industrial Injuries Advisory Council (IIAC) to review the evidence concerning the risk of cancer in firefighters. This position paper updates earlier reviews by the Council of the risk of testicular cancer in firefighters (2008) and a commissioned a review into the health effects (malignant and non-malignant) of working as a fire-fighter (2010).

A comprehensive review of the recent published literature relating to cancer in firefighters, together with a summary of potential carcinogens to which firefighters may potentially be exposed, has been carried out by members of IIAC.

There is substantial evidence that firefighters may potentially be exposed to a complex mixture of substances including several carcinogens; measurements during firefighting operations may be above the relevant Work Exposure Limit. It should be noted that many of these carcinogens are also common environmental contaminants, although generally at much lower concentrations than experienced by firefighters.

There are a large number of published studies investigating cancer risk in firefighters from many countries. There is consistent evidence that mortality and cancer incidence in firefighters for all cancers considered together do not show any excess risk compared to the general population. Increased risks associated with firefighting for specific cancer sites have been found but the types of cancer and the magnitude of the risk estimates vary considerably between studies and between countries, study date and length of employment of the firefighters. In addition, the risks are generally less than doubled.

Thus, the Council did not find consistent evidence that the risk of any type of cancer is more likely than not to be due to firefighting i.e. the risk was more than doubled. The exception was mesothelioma which is already covered by the scheme. The Council has therefore decided against recommending prescription for cancer in firefighters, but it remains open to the possibility of reviewing its position as the research evidence base continues to grow. The Council is aware of several ongoing studies of exposures and health effects among firefighters and will continue to monitor the literature closely. The Council also notes that firefighters may make a claim under the accident provision of IIDB for any disability or loss of faculty that can be shown to have resulted from their attendance at a specific fire. This not only applies to immediate injury but also to effects from the fire which are delayed and only become apparent at a later time.

This report contains some technical terms, the meanings of which are explained in a concluding glossary.

Background

1. In 2019 the House of Commons Environmental Audit Committee (EAC) published a report 'Toxic Chemicals in Everyday Life'. One section of the report reviewed environmental contamination around the Grenfell Tower site.

2. In addition to concerns about the health of the resident population in the vicinity of the Grenfell tower the EAC were concerned about the exposure of firefighters and clean-up workers to toxic chemicals and the potential adverse health effects following these exposures. The EAC drew attention to published studies that have found increased risks of cancer among firefighters. They suggested that the '*Government should update the Social Security Regulations so that the cancers most commonly suffered by firefighters are presumed to be industrial injuries. This should be mirrored in the UK's Industrial Injuries Disablement Benefits Scheme'.* Following this a formal request was made to the Industrial Injuries Advisory Council (IIAC) that they should review the evidence concerning the risk of cancer in firefighters.

3. IIAC notes that the Fire Brigades Union (FBU) has raised concerns about the long-term effects upon firefighters and others exposed to smoke and toxins as a consequence of the Grenfell Tower fire. Firefighters attending at the fireground on the day and days following the initial fire have raised concerns about psychological and physical injuries. IIAC recognise that the long-term effects upon those attending the Grenfell site will need to be kept under review.

4. This report reviews available evidence concerning the risk of cancer among firefighters; potential exposure to carcinogens are also discussed.

The Industrial Injuries Disablement Benefit Scheme

5. The IIDB Scheme provides non-contributory, 'no-fault' benefits for disablement because of accidents or prescribed diseases which arise during the course of employed earners' work. The benefit is paid in addition to other incapacity and disability benefits. It is tax-free and administered by the Department for Work and Pensions.

6. The legal requirements for prescription are set out in The Social Security Contributions and Benefits Act 1992 which states that the Secretary of State may prescribe a disease where s/he is satisfied that the disease:
    a. ought to be treated, having regard to its causes and incidence and any other relevant considerations, as a risk of the occupation and not as a risk common to all persons; and
    b. is such that, in the absence of special circumstances, the attribution of particular cases to the nature of the employment can be established or presumed with reasonable certainty.

7. Thus, a disease may only be prescribed if there is a recognised risk to workers in an occupation, and the link between disease and occupation can be established or reasonably presumed in individual cases.

The Role of the Industrial Injuries Advisory Council

8. IIAC is an independent statutory body established in 1946 to advise the Secretary of State for Social Security on matters relating to the IIDB scheme. The major part of the Council's time is spent considering whether the list of prescribed diseases for which benefit may be paid should be enlarged or amended.

9. In considering the question of prescription the Council searches for a practical way to demonstrate in the individual case that the disease can be attributed to occupational exposure with reasonable confidence; for this purpose, 'reasonable confidence' is interpreted as being based on the balance of probabilities.

10. Some occupational diseases are relatively simple to verify, as the link with occupation is clear-cut. Some only occur due to particular work or are almost always associated with work or have specific medical tests that prove their link with work, or have a rapid link to exposure, or other clinical features that make it easy to confirm the work connection. However, many other diseases are not uniquely occupational, and when caused by occupation, are indistinguishable from the same disease occurring in someone who has not been exposed to a hazard at work. In these circumstances, attribution to occupation depends on research evidence that work in the prescribed job or with the prescribed occupational exposures causes the disease on the balance of probabilities. The Council thus looks for evidence that the risk of developing the disease associated with a particular occupational exposure or circumstance is more than doubled (previous reports of the Council explain why this threshold was chosen).

11. The health effects arising from firefighting cannot be distinguished reliably from similar effects from exposures experienced in non-occupational circumstances, so the case for prescription rests on research evidence on the causal probabilities.

Introduction

12. In 2007 IIAC carried out an evaluation of the evidence concerning testicular cancer in firefighters following the publication of a Monograph from the International Agency for Research on Cancer (IARC) indicating that risks of testicular cancer were doubled among male fire fighters. The Council concluded that while there was evidence of an increased risk of testicular cancer in fire fighters, there was insufficient evidence that risks were clearly doubled and therefore insufficient evidence on which to recommend prescription (IIAC 2008). In 2009 IIAC commissioned a review into the health effects (malignant and non-malignant) of working as a fire-fighter (Graveling and Crawford 2010). The Council concluded that the evidence base for prescription described in the review was 'insufficiently compelling to warrant recommendation of prescription in relation to any particular health problem of fire-fighters' (IIAC 2010).

13. This current report first describes the evidence relating to exposure of firefighters to carcinogens. The epidemiological section evaluates review articles and meta-analyses published between 2006 and 2020 followed by a review of more recently published literature.

Exposure of firefighters to carcinogenic agents

The job

14. The work undertaken by firefighters differs considerably between countries and between locations within a country. Firefighters may have to deal with many different tasks, including fighting fires in domestic buildings or industrial sites, in woodland and other natural settings, on aircraft or ships, military sites and oil wells. Firefighters may also attend other emergencies such as road traffic accidents, flooding and terrorist incidents, and they undertake non-emergency tasks such as inspection of fire precautions on sites and education activities. The job can be full time or firefighters can be part-time, retained to respond to fires as and when they occur. Some firefighters are volunteers. Part-time and volunteer firefighters are mostly deployed in rural areas. Exposures to hazardous agents differ between location and setting.

15. The main tasks involved in fighting a fire are extinguishing or controlling the fire and then making the area safe and extinguishing small residual fires; these phases are sometimes referred to as knockdown and overhaul. The IARC Monograph on Firefighters observed that about 90% of fires in city buildings are either extinguished within 5 to 10 minutes or are left to burn and are fought from outside the building (IARC 2010). The second phase of the work at a fire can take much longer than the initial response. Exposure may differ between the two phases, both in the agents present and the magnitude of exposure. In the IARC Monograph it was estimated that in two fire departments in the USA, total firefighting activity during a year was around 48 to 50 hours. In a separate study in the USA, firefighters attended 57 fires in a year. In England in 2018/19 the 35,000 firefighters in the Fire and Rescue Service attended 182,000 fires[1]; assuming that on average around 25 firefighters[2] attended each fire that would correspond to around 130 fires per firefighter per year. During summer months in the UK grassland fires and other outdoor fires can make up a substantial part of the total number of the fires attended.

16. Firefighters may have different jobs or duties, e.g. driver, use of water hoses and pumps, use of ladders to access buildings etc. Basic protective clothing is worn by all firefighters and additional chemical protective clothing or respiratory protection is worn during specific risk situations. Exposures will also differ by specific duties at a fire and are dependent on the protective equipment worn.

---

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831136/detailed-analysis-fires-attended-fire-rescue-england-1819-hosb1919.pdf
https://www.ethnicity-facts-figures.service.gov.uk/workforce-and-business/workforce-diversity/fire-and-rescue-services-workforce/latest#:~:text=The%20data%20shows%20the%20number,time%20firefighters%20of%20all%20ranks

[2] Based on the typical number of firefighters deployed in London; https://www.london-fire.gov.uk/incidents/

Hazards present at fires

17. During a fire there is a complex mixture of chemicals and dusts in the air. Fires release a number of known or suspected carcinogens, including benzene, propylene, 1,3- butadiene, formaldehyde, polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). From samples taken at municipal structural fires or vehicle fires 14 different compounds accounted for 75% of the total volatile organic materials measured (Austin et al., 2001). These same compounds constituted approximately 65% of all volatile organic compounds in experimental fires, burning various materials commonly found in structural fires (Austin et al., 2001). Benzene was the dominant compound that is classified as carcinogenic to humans, along with toluene and naphthalene. The IARC Monograph listed 40 chemicals found in smoke at fires as definite human carcinogens (group 1), probable (2a) or possible human carcinogens (2b). In addition, firefighters may be exposed to a number of other hazardous substances, including carbon monoxide, sulphur dioxide, hydrogen cyanide, hydrogen chloride and airborne particulate matter.

18. The IARC Monograph summarised the published data on chemical concentrations measured during firefighting operations (ranges or means), which are shown in Table 1 along with the UK Workplace Exposure Limits (WELs), where available, and the cancer sites linked to exposure that were identified by the IARC as having sufficient evidence to be classified as group 1.

Table 1 Published data on chemical concentrations measured during firefighting operations from the IARC Monograph (2010)

Substance	Units	Wildland	Municipal	Training	Arson	IARC Classification	IARC cancer sites with sufficient evidence[3]	British WEL
Acetaldehyde	ppm	ND-0.26	ND-8.1		0.13[b]	2b	Oesophagus, Digestive tract, upper (both from alcohol consumption)	20
Asbestos	f/ml		2.7[a]	0-2.3[d]		1	Mesothelium, Lung, Ovary, Pharynx, Larynx	0.1
Arsenic	mg/m^3		0.14[a]			1	Lung, Skin, Urinary bladder	0.1
Benzene	ppm	0.004[a]-0.38	0.07-250	1.17[a]	<0.12[b]	1	Leukaemia and/or lymphoma	1
Benzofuran	ppm		0.2-2			2b	-	-
1,3-Butadiene	ppm		0.03-4.8			1	Leukaemia and/or lymphoma	1
Cadmium	mg/m^3		ND-8.1			1	Lung	0.025
Polychlorinated dibenzodioxins	ng/m^3		12-148			3	-	-
Dichloromethane	ppm		0.28[a]			2a	-	100
Ethyl benzene	ppm		0.01-6.0	0.38[a]		2b	-	100
Formaldehyde	ppm	0.01-0.79	ND-15		0.06-0.18	1	Nasopharynx, Sinonasal, Leukaemia and/or lymphoma	2

[3] https://monographs.iarc.fr/wp-content/uploads/2019/07/Classifications_by_cancer_site_127.pdf

Furan	ppm		0.2-2			2b	-	-
Isoprene (2-Methyl-1,3-butadiene)	ppm			0.17[a]		2b	-	-
Lead	mg/m^3		0.03[a]			2a (lead compounds)	-	0.15
Naphthalene	ppm		0.1-2.1	0.42[a]	*	2b	-	10
PM_{10}	mg/m^3	3[b]				-	Lung (for outdoor air pollution)	-
PM respirable	mg/m^3	0.02[c]-10.5	ND-25.7		ND-1.2	-	Lung (for outdoor air pollution)	5
Pentachlorophenol	mg/m^3	0.2[a]-44.9	14-300		0.2-31.6	1	Leukaemia and/or lymphoma	500
Polycyclic aromatic hydrocarbons	mg/m^3		6.4-470	10.7[a]		-	-	-
Polychlorinated biphenyls	mg/m^3		2.8-56			1	Skin	0.1
Crystalline silica	mg/m^3		0.04-0.35			1	Lung	0.1
Styrene	ppm		0.003-2.0	0.54[a]		2a	-	100
Sulphuric acid	mg/m^3		ND-28.5		0.3[b]	1	Larynx (acid mists)	0.05
Tetrachloroethylene	ppm		0.064-0.14			2a	-	20
Trichloroethylene	ppm		0.11-0.18			1	Kidney	100
Trichloromethane (chloroform)	ppm		0.96-660			-	-	2
Trichlorophenol	ppm		0.1[a]			2b		-

* 30-200 mg/m^3 a – mean b – maximum c – geometric mean d - from helmets and fumes of firefighters ND - not detected

19. Eleven of the entries in the table relate to substances classified as definite human carcinogens (IARC 1), mostly either cancers in the respiratory system or leukaemia and/or lymphoma. The remaining entries are mostly for 'probable' or 'possible' carcinogenic substances.

20. Based on these data, during firefighting exposures to many carcinogenic substances can be in excess of the WEL. However, breathing apparatus and other respiratory protection is commonly used when fighting fires, which will reduce inhalation of hazardous substances. The concentrations reported in the table generally do not take into account the use of respiratory protection. However, IARC noted that during wildfires where respiratory protection is not worn, fire fighters may be involved in heavy manual work that would increase their breathing rate and as a consequence the amount of chemicals inhaled would be greater than for workers engaged in less demanding work in similar conditions.

21. There have been over 30 scientific papers published since the IARC meeting that describe exposures of fire fighters. These confirm that fire fighters are exposed to a number of carcinogens; the levels of exposure are mostly similar to or lower than described in the IARC Monograph. For example, Fent *et al* (2014) describe PAH and benzene exposures for two fire scenarios relating to structural fires. Airborne PAH concentrations were between about 2 and 20 mg/m^3, of which around 2% to 6% was benzo(a)pyrene (classified by IARC as a Group 1 carcinogen). In the last ten years there has been increased scientific interest in the possibility of dermal uptake of carcinogenic chemicals and Fent *et al* measured skin contamination of PAHs and also monitored for metabolites of PAH in the urine of fire fighters and for benzene in their exhaled breath. The results suggested that despite wearing full protective clothing and respirators, there was increased exposure indicated from the urine samples, which the authors suggest was due to skin exposure around the neck (increase in PAH exposure on the skin was around 0.001 mg/cm^2). However, the levels of exposure were low; for example, the exhaled benzene concentrations were similar to those reported for non-smoking automobile mechanics. Sjostrom *et al* (2019) measured air concentrations of benzene, 1,3-butadiene and particles, and PAH in the air and on the skin of firefighters and police forensic investigators. Exposures were all below Swedish occupational exposure limits and PAH contamination of the skin was low (<0.02 mg/cm^2). Stec *et al* (2018) also measured PAH in the air along with contamination on the skin and clothing of firefighters. They found low levels of PAH in the air of fire stations and fire engines, and varying levels of contamination on the skin (<55 mg/cm^2) and protective clothing of the firefighters (mostly < 250 mg/cm^2).

22. Alexander and Baxter (2014) reported low level contamination of polybrominated diphenyl ethers (PBDEs) on clothing. Fernando *et al* (2016) measured methoxyphenols (MPs) and polycyclic aromatic hydrocarbons (PAHs) during training exercises involving wood smoke –

identifying potential for skin exposure, with the increase in urinary PAH metabolite concentrations being similar to that seem amongst cigarette smokers. Bott *et al* (2017) measured diesel particulate matter (DEP) and polycyclic aromatic hydrocarbons in fire stations, showing that most DEP concentrations were less than 5 mg/m^3, measured as elemental carbon, which is comparable to the exposure of bus and truck drivers. Engelsman *et al* (2019) reported metals and semi-volatile organic compounds as surface contamination in Australian fire stations. Relatively low concentrations across fire fighter clothing ensemble, inside vehicle cabins, and within fire stations were measured for chromium (<0.05 µg/cm^2), lead (<0.06 µg/cm^2), nickel (<2.5 µg/cm^2) and manganese (<1.0 µg/cm^2).

23. Pedersen et al (2019) investigated changes in chemical exposures over time encountered by Danish firefighters. They showed there have been a number of historical changes, some of which will have increased chemical exposures during firefighting and some that will have decreased exposure. The toxicity of smoke combustion from plastic materials introduced in the 1950s was seen to have increased, diesel engines on fire vehicles were introduced in the 1960s and will have introduce new carcinogenic exposures for fire fighters, and new tasks for fire fighters involving chemical clean-up in the 1970s and traffic accidents in the 1990s added further risks. However, the authors noted that the mandatory use of effective breathing apparatus in the 1970s, use of mechanical exhaust systems in the 2000s, and emission reductions for diesel engines in the 2010s would all have reduced carcinogenic exposures in the profession.

24. Overall, it is clear that firefighters may be exposed to a mixture of carcinogenic substances during their work. The levels of exposure vary considerably from day to day and from person to person because of the diverse work undertaken. While some exposures may exceed the relevant legal limits (WELs in Britain), the use of respiratory protection and protective clothing should reduce the risks. Concern about skin exposure to chemicals and contamination of equipment and clothing needs further scientific investigation and additional control measures, but it is unlikely that such exposures importantly add to the risk of cancer. It should be recognised that many of the carcinogens to which firefighters are exposed are also common environmental contaminants, e.g. formaldehyde is often found in the air inside homes and offices arising from furnishings, flooring or other installations. Benzene is found in outdoor air in cities from road traffic emissions and inside buildings from cigarette smoke.

Epidemiological Evidence of Cancer Risk in Firefighters

Reviews and meta-analyses

25. An early review and meta-analysis by McMasters et al (2006) of cancer mortality and incidence included 32 studies of firefighters. Three criteria

were used to assess the probable, possible, or unlikely risk for 21 cancers: the pattern of meta-relative risks (meta-RR), study type, and heterogeneity testing. The authors concluded that firefighters had a probable cancer risk for multiple myeloma (meta-RR = 1.53 95% confidence interval (CI) 1.21–1.94), non-Hodgkin lymphoma (meta-RR = 1.51, 95% CI 1.31–1.73), and prostate (meta-RR = 1.28, 95% CI 1.15–1.43). In addition, the highest meta-RR was found for testicular cancer (meta-RR = 2.02; 95%CI 1.30–3.13). Eight additional cancers were listed as having a "possible" association with firefighting.

26. In the same year a meta-analysis of results for cancers of the colon, bladder, kidney, and brain, non-Hodgkin's lymphoma and leukaemia among firefighters from 16 studies (13 cohort, 3 case-control) was published (Youakim 2006). When only cohort mortality studies were considered the risk was not elevated for any of the six cancers. When both cohort and case-control mortality studies were considered, however, there was a mild increase in risk for kidney cancer and non-Hodgkin's lymphoma, with a summary relative risk (meta-RR) of 1.22 (95%CI 1.02–1.43) and 1.40 (95%CI 1.20–1.60), respectively. Duration of employment was associated with significant increases in mortality associated with 30 or more years of employment risk for colon cancer, meta-RR = 1.51 (95%CI 1.05–2.11); kidney cancer, meta-RR = 6.25 (95%CI 1.70–16.00); brain cancer, meta-RR 2.53 (95%CI 1.27–7.07); and leukaemia, meta-RR = 2.87 (95%CI 1.43–5.14).

27. The McMaster's study was updated up to 2007 during the monograph meeting for the evaluation of cancer risks for firefighters (IARC 2010) to include 2 large studies (Ma et al 2006; Bates 2007); unlike McMasters, proportional mortality studies (PMR) were excluded. The results showed statistically significantly raised risks for three of the four cancer sites highlighted by McMasters: non-Hodgkin lymphoma (meta-RR = 1.21, 95% CI 1.08–1.36, 7 studies); testicular cancer (meta-RR = 1.47; 95%CI 1.20–1.80, 6 studies); prostate cancer (meta-RR = 1.30; 95% CI: 1.12–1.51, 16 studies).

28. In 2010 IIAC commissioned a systematic review by the Institute of Occupational Medicine (IOM) of the evidence relating to occupational health risks in firefighters, primarily cancers but also including other causes of ill health (Graveling and Crawford 2010). An information note was published by IIAC following this report. IOM found 34 relevant papers relating to 23 different kinds of cancer. Up to 17 papers were found for some commonly studied tumours such as those affecting the stomach, skin, prostate and brain, and a dozen or more research reports on cancers of the pancreas, bladder, colon, rectum, oesophagus, kidney and blood. The 34 papers included 7 review articles and some of the individual papers appeared to include overlapping cohorts of firefighters. The IOM discussed this and took care to avoid double-counting and to only include the key data source where clear overlap occurred.

29. The IOM report gives very detailed results in the text and tables for each separate cancer; the IIAC information note gives a summary table by cancer site with a range of RRs. The majority of the papers are also included in the IARC monograph with about 6 additional more recent papers. No meta-analyses were carried out by IOM; however, for each cancer site the authors gave the range of RRs from all the relevant papers and then an estimate of a ‘collective’ range of RRs that they considered ‘reasonable’. Although RRs exceed 2.0 in some of the individual studies, in general the reviewers concluded that there was little consistent evidence that risks were elevated in fire-fighters for any of the cancer sites considered.

30. Brantom et al 2018 carried out a review of the literature published since the IARC review of 2007, focussing on 21 cancer sites. Over 600 publications were screened from which the authors identified 6 cohort studies on firefighters, described in 8 papers and 3 case-control studies focusing on firefighters. For specific cancer sites, there were 14 other case-control studies which examined occupational links in general and included mentions of firefighters or an exposure pertinent to firefighters.

31. Each study was scored for quality, and conclusions were reached for each of the 21 cancer sites, taking account of the results of the study and the plausibility of an association, based upon the known chemical exposures of firefighters. The combined evidence for each specific site was classified in two dimensions: one which focused on the presence of statistically significant associations of cancer with the occupation of firefighter (None, Limited, Mixed, Consistent) and the second which was based on the qualities of the study, the existence of a plausible mechanism and a demonstration of a trend with categories: Very weak, Weak, Moderate, Strong.

32. The report discusses potential confounding and/or effect modifying factors related to firefighters including: alcohol (up compared with the general population); smoking (slightly less than the general population); obesity (small excess); medical examination frequency (often mandatory e.g. every 3 years in the London Fire Brigade); shift work; ethnicity. There is considerable discussion in the Brantom review about consistency across studies, previous reviews etc.

33. Of the cohort studies reviewed, a US study by Daniels et al 2014 identified significantly raised mortality and/or incidence from several cancer sites including buccal, pharynx, large intestine, kidney, lung, oesophagus and rectum, and double the risk for mesothelioma. Pukkala et al (2014) found significantly raised risks for Nordic country firefighters for lung, prostate and skin cancer (both melanoma and non-melanoma skin cancer (NMSC)) with more than doubled risk for prostate (aged 30-49 years at follow-up), mesothelioma (aged 70+) and nearly doubled for lung (aged 70+). A Scottish study by Ide et al (2014) found high incidence rates for melanoma and kidney cancer. There were no significant excesses in a French cohort study (Amadeo et al 2015). The Australian study by Glass et al (2016) found an excess risk

for all cancer (1.09) and significant but not doubled risks for male reproductive cancers, prostate and melanoma. Two papers by Ahn et al (2012, 2015) of Korean emergency responders of whom approximately 81% were firefighters found significantly raised SIRs compared with the general population for colon and rectum, and NHL but no significant excess for mortality. The case-control studies reviewed also identified significant excesses from several cancer sites. Risks were doubled for small cell lung (US study by Tsai et al 2015), head and neck cancer for ‘ever employed’ as a firefighter (ICARE European study, Paget-Bailly et al 2013) and mesothelioma of the pleura (US study, Roelofs et al 2013).

34. Brantom et al also reviewed 4 studies that estimated the risk of mesothelioma in firefighters. Daniels et al (2014) found double the risk for both mortality (Standardised Mortality Rate (SMR) =2.00, 95%CI 1.03-3.49) and incidence (Standardised Incident Rate (SIR) = 2.00, 95%CI 1.31-2.93). SIRs from the other 3 studies were 1.55 (95%CI 0.90-2.48) (Pukkala et al 2014), 1.34 (95%CI 0.75-2.21) (Glass et al 2016) and 2.2 (95%CI 1.4-3.4) (Roelofs et al 2013); 10 of the 17 cases in the Nordic study by Pukkala et al were 70+ years old at incidence (SIR=2.59, 95%CI 1.24-4.77). An overall excess of mesothelioma incidence was found in the meta-analysis by Cajens et al (meta-RR=1.46 (95%1.01-1.90) – see below.

35. A recent review and meta-analysis carried out by Soteriades et al (2019) included 49 studies published between 1966 and 2007. Using criteria modified from the MOOSE guideline (Stroup et al 2002) they categorised each study into weak, adequate, and good. It should be noted that the numbers of studies reporting results for each of the cancer sites varied widely; most were based on under 25 separate estimates. Statistically significant associations were found between firefighting and cancers of bladder, brain and CNS, and colorectal cancers. Statistically significant (not doubled) associations of firefighting (all studies) were found for brain, NHL, colorectal, melanoma, prostate, testis, kidney and lymphomas.

36. A similar meta-analysis published in the same year (Jalilean et al. 2019) included all papers published up to 2018. 50 papers were included in the review and 48 in the meta-analysis; estimates of risks at different cancer sites were again based on fewer than 25 separate estimates. Significantly elevated (generally less 1.5) meta-SIRs were found for cancers of the colon, rectum, prostate, testis, bladder, thyroid, pleura and melanoma; significant meta-SMRs were found for rectal cancer and NHL (both <1.5). Following this publication, a letter published by Casjens et al (2019) criticised several aspects of the methodology used in the meta-analysis. These included use of multiple estimates of specific cancer sites from one study (thus increasing the weight put on this study), inappropriate aggregation of cancer sites e.g. some lymphomas, analysis of males and females together, and omission of data from 6 population case-control studies.

37. In addition to overall risk estimates, a recent meta-analysis compared cancer risks among professional firefighters with employment starting from different decades (before 1950, between 1950 and 1970, after 1970) and different geographic areas (North America, Europe, Korea/Australia/New Zealand) (Casjens et al 2020). The authors adapted the search terms from Jalilian et al. (2019) and included 25 cohort studies published up to the end of 2018 with SIRs or SMRs using the general population as reference. The overall cancer meta-SIR of firefighters was similar to the general population (meta-SIR 0.97 0.89–1.05) and there was no trend by decade of employment. Statistically significant elevated meta-SIR estimates were found for mesothelioma (meta-SIR = 1.46, 95% CI 1.01–1.90), bladder cancer (meta-SIR = 1.14, 95% CI 1.04–1.23) and colon cancer (meta-SIR = 1.11, 95% CI 1.00–1.21) but no trends over decade of employment. However, increased incidence risks over time were shown for malignant melanoma of the skin, overall skin cancer, prostate, and testis cancer. The meta-SIR for stomach cancer was elevated in firefighters in the earliest employment period starting before 1950 (meta-SIR = 1.75, 95% CI 1.31–2.19) and decreased afterwards. In addition, a statistically significant reduced meta-SIR was observed for trachea and lung cancer in the period of employment starting after 1970. The meta-SIR of liver and brain cancer among firefighters was slightly lower than expected especially in the time of later employment.

38. The studies from Korea/Australia/New Zealand (80% of firefighters in these studies started work after 1970) had statistically significantly raised meta-SIRs for melanoma (1.43, 95%CI 1.27, 1.58; 2 studies), prostate (1.23, 95%CI 1.11,1.34; 3 studies) and testis (1.47, 95%CI 1.01,1.83). Bladder cancer incidence was statistically significantly raised only in USA/Canada (1.14, 95%CI 1.04,1.25; 2 studies) and pancreatic cancer was statistically significantly increased only in Europe (1.23, 95%CI 1.03, 1.45). However, lung cancer was reduced significantly in KOR/AUS/NZL.

Recent meta-analyses of Prostate cancer

39. A meta-analysis of 25 studies found a small excess risk of prostate cancer in firefighters (Sritharan 2017, abstract only). Ever employment as a firefighter gave a meta-RR of 1.15 (95% CI 1.04–1.27). Similar results were found for different study designs; incidence studies had a meta-RR of 1.17 (95% CI 1.07–1.28) and mortality studies had a meta-RR of 1.12 (95% CI 0.92–1.36).

40. A meta-analysis of 6 longitudinal studies (4 cohort studies and 2 case-control studies) published between 2008 and 2017 found a slightly larger excess risk of prostate cancer (Mehlum et al, 2018 abstract only). The meta-RR for incidence for cohort studies was 1.20 (95 % CI 1.05–1.36). Results from the two case-control incidence studies gave

meta-RR 1.24 (0.90–1.70). Meta-analysis of all eight risk estimates gave meta-RR 1.19 (1.08–1.32).

Recent papers

41. Similar findings to those of the meta-analyses have been reported in some more recent papers. A Canadian study linked data for a cohort (CanCHEC) formed from a 20% sample of people from the 1991 census to the Canadian cancer registry for follow up (Harris et al., 2018). Hazard ratios were estimated for about 4500 firefighters compared to workers in other occupations. There was no increased risk in firefighters for all cancers together. Elevated risks were noted for Hodgkin's lymphoma (Hazard Ratio (HR): 2.89, 95%CI: 1.29-6.46), melanoma (HR: 1.67, 95%CI: 1.17-2.37), and prostate cancer (HR: 1.18, 95%CI: 1.01-1.37).

42. In an earlier study of Australian male volunteer fighters Glass et al (2017) found reduced risks of mortality and cancer incidence overall and in most major cancer categories, compared with the general population. A significant but small increase in prostate cancer was found (SIR=1.12, 95%CI 1.08-1.16). Similar results were found in a study of female volunteer firefighters (Glass et al 2019). There was a significant excess for melanoma (SIR=1.25, 95% CI 1.05-1.46).

43. Another linkage study of firefighters has reported updated cancer incident data from 1961-2009 (Bigert et al 2020). Approximately 8100 firefighters were identified in the Swedish component of the Nordic Occupational Cancer (NOCCA) cohort which includes six million people who participated in one or more of the population censuses in 1960, 1970, 1980 and 1990. The census data were linked to the Swedish Cancer Registry for the 1961–2009 period, extending a previous NOCCA follow-up time by 4 years. There was no excess for all cancer sites combined; however, but a significant excess was found for non-melanoma skin cancer (SIR = 1.48, 95% CI 1.20–1.80) but no positive relationship between risk and work duration. There was a small but significant increased risk of prostate cancer among firefighters with service times of 30 years or more (SIR = 1.14, 95% CI 1.01–1.29).

44. A cohort study of Spanish firefighters employed in 2001 and followed up to 2011 found no differences in age-standardised all-cause mortality or all-cancer mortality relative to all other occupations (Zhao et al 2020). A significant excess was found for mortality from cancer of larynx (RR = 1.77, 95% CI: 1.01–3.09) and hypopharynx (RR = 2.96, 95% CI: 1.31–6.69.

45. The risk of head and neck cancer among male firefighters was investigated in a large population-based case–control study of head and neck cancer from the greater Boston area using self-reported occupational history (718 cases and 905 controls) (Langevin et al 2020). Occupational history as a firefighter was reported for 11 cases

and 14 controls. There was an increased risk for hypopharyngeal and laryngeal squamous cell carcinoma among professional municipal firefighters who had a light or no smoking history (OR=8.06, 95% CI 1.74 to 37.41), with significantly increasing risk per decade as a firefighter (OR=2.10, 95% CI 1.06 to 4.14).

46. An update of a study of nearly 30,000 US firefighters compared their mortality with the US general population via life table analyses (Pinkerton et al 2020). Full risk-sets, matched on attained age, race, birthdate and fire department were created and analysed using the Cox proportional hazards regression to examine exposure-response associations between selected mortality outcomes and exposure surrogates (exposed-days, fire-runs and fire-hours) obtained by linking work histories with JEMs. Models were adjusted for a potential bias from healthy worker survivor effects (HWSE) by including a categorical variable for employment duration. Mortality was elevated for all cancers (SMR=1.12; 95% CI 1.08 to 1.16), mesothelioma (SMR=1.86; 95% CI 1.10 to 2.94), NHL (SMR=1.21; 95% CI 1.03 to 1.42) and cancers of the oesophagus (SMR=1.31; 95% CI 1.10 to 1.55), intestine (SMR=1.27; 95% CI 1.14 to 1.40), rectum (SMR=1.32; 95% CI 1.07 to 1.61), lung (SMR=1.08; 95% CI 1.02 to 1.15) and kidney (SMR=1.22; 95% CI 1.00 to 1.47). Positive exposure-response relationships were observed for deaths from lung cancer and leukaemia. The authors suggest that a strength of their analysis is the assessment of exposure-response relations accounting for the HWSE and comment that 'negative confounding by employment duration obscured positive exposure-response relations for several outcomes in unadjusted models'.

47. A study of cancer risk in over 100,000 career Florida firefighters including 5000 + females assessed over a 34-year period linked Florida firefighter employment records with the Florida Cancer Data System registry data (Lee et al 2020). This paper used a case-control approach in which odds ratios were estimated comparing each cancer site with all other cancers except the cancer of interest in non-firefighters. Stratified analyses were carried out for male firefighters by cancer stage at diagnosis (early [localized] and late [regional and distant] stage) and age at diagnosis (younger than 50-years-old and 50 years and older). Overall, male firefighters were at increased risk of melanoma (OR = 1.56; 1.39-1.76), prostate (OR = 1.36; 1.27-1.46), testicular (OR = 1.66; 1.34-2.06), thyroid (OR = 2.17; 1.78-2.66) and late-stage colon cancer (OR = 1.19;1.00-1.41). Female firefighters showed significantly elevated risks of brain (OR = 2.54; 1.19-5.42) and thyroid (OR = 2.42; 1.56-3.74) cancers and an elevated risk of melanoma (OR = 1.68; 0.97-2.90).

48. Compared to male non-firefighters with cancer, male firefighters were at increased risk of early-stage: melanoma (OR = 1.37; 1.19-1.57), prostate cancer (OR = 1.13; 1.03-1.23), testicular cancer (OR = 1.39; 1.07-1.82), and thyroid cancer (OR = 1.78; 1.38-2.31). They were at

decreased risk of early-stage cancers for liver (OR = 0.30; 0.16-0.56), larynx (OR = 0.62; 0.43-0.90), and lung (OR = 0.68; 0.54-0.86). Male firefighters were also at increased risk of late-stage thyroid (OR = 2.70; 1.94-3.76), prostate (OR = 1.42; 1.19-1.68), and testicular (OR = 1.69; 1.12-2.54) cancers, and decreased risk of myeloid (OR = 0.70; 0.49-0.99) and larynx (OR = 0.18; 0.07-0.48) cancers.

49. Among male firefighters there was additional evidence of increased cancer risk younger than the age of 50 vs 50 years and older for thyroid (OR = 2.55; 1.96-3.31 vs OR = 1.69; 1.22-2.34), prostate (OR = 1.88; 1.49-2.36 vs OR = 1.36; 1.26-1.47), testicular (OR = 1.60; 1.28-2.01 vs OR = 1.47; 0.73-2.94), and melanoma (OR = 1.87; 1.55-2.26 vs OR = 1.42; 1.22-1.66) cancers. The authors suggest that the excess risk for early-stage cancers in firefighters may be due, in part to the increased medical surveillance and routine medical care they receive.

Dose-response analyses

50. None of the epidemiological studies measure or estimate any of the potential exposures encountered during firefighting for individual study workers. The work of firefighters also varies considerably from day to day. Some studies use proxy exposure variables such as length of employment, date of hire, number of ‘fire hours’ or number of ‘fire-runs’ (linkage of work histories with other information, for example a Job Exposure Matrix).

51. Many studies do not provide results by dose-response proxy variables, particularly those published before 2000 (see IARC 2007). The US cohort study by Baris *et al.* (2001) found that the risks of mortality from colon cancer (SMR, 1.68), kidney cancer (SMR, 2.20), non-Hodgkin lymphoma (SMR, 1.72), multiple myeloma (SMR, 2.31), and benign neoplasms (SMR, 2.54) were increased in firefighters with at least 20 years of service. A New Zealand study found an excess of testicular cancers overall (SIR, 1.55; 95% CI: 0.8–2.8) which increased by year of hire (for 1990–1996, SIR 3.0 (95% CI: 1.3–5.9) (Bates et al 2001).

52. The review by Brantom et al (2018) of papers published since the IARC monograph (2007) highlights several studies showing raised risks in dose-response analyses. The US study by Daniels et al (2014, 2015) found increasing risk for stomach cancer and NHL by length of service with risks for 30+ years of 1.53 (95%CI 1.06-2.15) and 1.47 (95%CI 1.01, 2.06) for stomach cancer and NHL respectively. Glass (2016) in a study of paid Australian firefighters found increased risk by duration of service for kidney cancer: 10-20 yrs. 6.95 (0.85-56.81), > 20 yrs. 8.19 (1.01-66.62); Lympho-haematopoietic cancer 10-20 yrs. 2.38 (1.08-5.26), > 20 yrs. 3.08 (2.32-7.20); NHL 10-20 yrs. 2.12 (0.71-6.34), ≥ 20 yrs. 3.67 (1.28-10.54); prostate cancer RR for 3rd tertile of cumulative incidents vs 1st All fires 2.55 (1.45-4.50), Structural fires 2.45 (1.40-4.26), Vehicle fires 2.60 (1.50-4.54). An increase by duration of

employment was also found for prostate cancer for male volunteer firefighters; 10-20 years 1.07 (0.91 to 1.26), >20 years 1.15 (1.01 to 1.31) (Glass et al 2017).

53. As noted above the most recent meta-analysis found increased incidence risks by increased year of starting employment for malignant melanoma (1950-1970 meta-RR=1.26 95%CI1.08-1.44, >1970 95%CI 1.27,1.58), prostate cancer (1950-1970 meta-RR=1.08 95%CI1.00-1.15, >1970 meta-RR=1.18 95%CI 1.09,1.27) and testis cancer (>1970 meta-RR=1.54 95%CI 1.29,1.79) (Casjens et al 2020).

Discussion of epidemiological evidence

54. Mortality rates and cancer incidence for all cancers considered together for firefighters do not show an excess risk compared to the general population in most of the studies or meta-analyses. Excess risks associated with firefighting for specific cancer sites have been found but the cancer sites and the risk estimates vary considerably between studies and meta-analyses. Several find excess risks for prostate; testis (reviewed by IIAC in 2008); non-Hodgkin lymphoma. The evidence is less consistent for multiple myeloma, leukaemia; bladder; kidney; skin (both melanoma and NMSC); mesothelioma; thyroid. For all these cancer sites the risk estimates are generally less than doubled with many being under 1.5.

55. There are no studies that investigate cancer risk in relation to individual measured exposure to individual carcinogens. Proxy variables are used in a few studies, for example duration of employment, number of fire hours or fire runs. The risk for some cancer sites has been found to increase as the proxy variable increases e.g. by increased duration of employment, but there is no consistent pattern by cancer site or between studies.

56. The evidence base for firefighters includes studies from many different countries. The meta-analysis by Casjens et al (2020) highlighted the varying estimates between broad groups of countries. Casjens et al also investigated changes over the years of diagnosis with some cancer sites, for example melanoma and prostate, showing increases in more recent studies. They suggest that, for both these cancer sites, this may partly be due to improved screening and earlier diagnosis.

57. The work carried out by firefighters varies considerably and this has probably contributed to the lack of consistency in the results.

58. In addition, none of the studies take into account the provision and use of PPE. This will also have changed over the time period covered by the studies reviewed here.

Conclusions

59. There is a substantial and growing body of research that provides evidence that firefighters may potentially be exposed to a complex mixture of chemicals within their occupation. Some of these chemicals are currently classified as definite or probable human carcinogens. Moreover, data on measured exposures during firefighting operations suggest that there is the potential to be exposed to levels of some of these chemicals above the Workplace Exposure Limit (WEL). Whilst appropriate use of PPE should reduce the levels of exposure to individuals, there are few (if any) data quantifying these protective effects. It should be noted that many of these carcinogens are also common environmental contaminants. e.g. in indoor and outdoor air, in cigarette smoke etc

60. There are a large number of published studies investigating cancer risk in firefighters from many countries. There is consistent evidence that mortality and cancer incidence in firefighters for all cancers considered together do not show any excess risk compared with the general population. Although there is a tendency for excess risks to be found associated with firefighting in several cancer sites the risk estimates vary widely across studies and between countries, era of study and length of employment.

61. The Environmental Audit Committee requested that IIAC evaluate evidence *so 'that the cancers most commonly suffered by firefighters are presumed to be industrial injuries'.* IIAC recently wrote two extensive reviews on the subject of presumption for prescribed diseases (IIAC 2014, IIAC 2015). However, as explained in the introduction, IIAC considers the evidence for prescribing any disease along the principle of the balance of probabilities. In practice, for diseases that are not only associated with occupational factors, this requires consistent evidence from large, high quality research studies that the occupation causes a doubling of the risk of the disease i.e. the disease is more likely than not to be caused by the occupation or occupational exposure.

62. Our review of the evidence in firefighters shows that there is evidence for risk estimates for some cancers to be greater than 1 in relation to firefighting. However, the studies are consistent in showing that the majority of these elevated risks are less than 1.5 and, with the exception of mesothelioma, none are more than doubled (mesothelioma is already a prescribed disease related to asbestos exposure).

63. It is therefore the conclusion of the Council, at the current time, that there is insufficient evidence for any cancer, with the exception of mesothelioma (already covered), to reach the required threshold for it to become a prescribed disease for firefighters. This, therefore, also means that presumption cannot be assumed for firefighters for those cancers.

64. However, the Council remains very vigilant for any new data that would enable prescription of any of these cancers. The Council is aware of several ongoing studies of exposures and health effects among firefighters and will continue to monitor the literature for future published reports and papers and will maintain a low threshold for reviewing this topic at any time in the future.

Prevention

65. As highlighted in this report firefighters may potentially be exposed to several different carcinogens when fighting fires or when cleaning up after a fire and exposure may also result from contact with contaminated clothing, PPE or the work environment. Regulation 7(7) of the Control of Substances Hazardous to Health Regulations (COSHH) 2002 requires employers to ensure that exposure to any carcinogen is reduced to the lowest reasonably practicable level. Options to eliminate exposure are limited and substitution with safer alternatives is clearly not practical so there must necessarily be a greater focus on suitable PPE to reduce exposure whilst on fire duties. Safe procedures should be established and regular training for incident commanders and firefighters should be provided for:
(i) removal, storage and cleaning of contaminated clothing;
(ii) cleaning of fire appliances and other work areas.
COSHH also requires that employers should carry out risk assessments before commencing any work to evaluate all potential risks and implement steps to prevent exposure to employees of relevant hazardous substances. For firefighters this should include all potential scenarios including extreme incidents such as the Grenfell Tower fire and also training exercises.

66. Generic risk assessment advice and operational guidance is provided by the Home Office:
https://www.gov.uk/government/collections/operational-guidance-for-the-fire-and-rescue-service#generic-risk-assessments

67. There are two British Standards which also contain useful advice:
    a. **BS-EN 469:2000 'Protective Clothing for Firefighters – Performance requirements for protective clothing for firefighting activities'** includes advice on contamination and emphasises the importance of hygiene practices after exiting a fire incident including not entering the fire truck with contaminated clothing, procedures for clean clothing at site, putting contaminated clothing in closed bags to avoid cross-contamination of the truck or other items, cleaning of contaminated clothing and use of showers on return to the station.
    b. **BS-EN 8617:2019 'Personal Protective Equipment for Firefighters. Cleaning, maintenance and repair – Code of practice'** provides more advice on cleaning and

decontamination including advice that the person handling contaminated clothing or PPE should wear appropriate PPE when cleaning it.

68. The Fire Brigades Union has also produced some simple guidance for firefighters: Minimising firefighters' exposure to toxic fire effluents - Interim Best Practice Report https://www.fbu.org.uk/publication/minimising-firefighters-exposure-toxic-fire-effluents

Glossary

PPE: Personal protective equipment - equipment which will protect the user against health or safety risks at work. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses.

WEL: Workplace exposure limit - British occupational exposure limits that are set to protect workers from exposure to toxic substances, either over a short-term — a short-term exposure limit (STEL, 15 minutes) or long-term — a time-weighted average (TWA, 8 hours).

IARC: International Agency for Research on Cancer.

Types of study

Cohort study: A study which follows up a population of individuals (usually defined by a workplace) over time and compared the incidence rate of disease or mortality among those within the cohort or with an external comparison population. The outcome is expressed as a Rate Ratio or Relative Risk, Standardised Incidence Ratio, Standardised Registration Ratio, or Standardised Mortality Ratio, depending on the type of analysis and the disease outcome being studied.

Case-control study: A study which compares people who have a given disease (cases) with people who do not (non-cases, also known as controls) in terms of exposure to one or more risk factors of interest. Have cases been exposed more than non-cases? The outcome is expressed as an Odds Ratio, a form of Relative Risk. In a nested-case control study, cases and controls are sampled from the members in a cohort study – often, all the cases occurring in the cohort and a sample of non-cases.

Measures of association

Statistical significance and P values: Statistical significance refers to the probability that a result as large as that observed, or more extreme still, could have arisen simply by chance. The smaller the probability, the less likely it is that the findings arise by chance alone and the more likely they are to be 'true'. A 'statistically significant' result is one for which the chance alone probability is suitably small, as judged by reference to a pre-defined cut-point. (Conventionally, this is often less than 5% ($p<0.05$)).

Relative Risk (RR): A measure of the strength of association between exposure and disease. RR is the ratio of the risk of disease in one group to that in another. Often the first group is exposed and the second unexposed or less exposed. A value greater than 1.0 indicates a positive association between exposure and disease. (This may be causal, or have other explanations, such as bias, chance or confounding.) RR is measured or approximated by other measures in this glossary, such as the Odds Ratio, Standardised Incidence Ratio and Standardised

Mortality Ratio.

Odds Ratio (OR): A measure of the strength of association between exposure and disease. It is the odds of exposure in those with disease relative to the odds of exposure in those without disease, expressed as a ratio. For rare exposures, odds and risks are numerically very similar, so the OR can be thought of as a Relative Risk. A value greater than 1.0 indicates a positive association between exposure and disease. (This may be causal, or have other explanations, such as bias, chance or confounding.)

Standardised Mortality Ratio (SMR): A measure of the strength of association between exposure and mortality; a form of Relative Risk in which the outcome is death. The SMR is the ratio of the number of deaths (due to a given disease arising from exposure to a specific risk factor) that occurs within the study population to the number of deaths that would be expected if the study population had the same rate of mortality as the general population (the standard).

By convention, SMRs (and proportional mortality ratios, as described below) are usually multiplied by 100. Thus, an SMR (or PMR) of 200 corresponds to a RR of 2.0. For ease of understanding in this report, SMRs (or PMRs) are quoted as if RRs, and are not multiplied by 100. Thus, a value greater than 1.0 indicates a positive association between exposure and disease. (This may be causal, or have other explanations, such as bias, chance or confounding.)

Proportional Mortality Ratio (PMR): A PMR is the proportion of observed deaths from a given cause in a given population divided by the proportion of deaths from that cause expected (in a standard population). The value is often expressed on an age-specific basis or after age adjustment. It is a form of Relative Risk.

Hazard ratio: A measure of how often a particular event happens in one group compared to how often it happens in another group, over time. In cancer research, hazard ratios are often used in clinical trials to measure survival at any point in time in a group of patients who have been given a specific treatment compared to a control group given another treatment or a placebo. A hazard ratio of one means that there is no difference in survival between the two groups. A hazard ratio of greater than one or less than one means that survival was better in one of the groups.

Other epidemiological terms

Prevalence: is the proportion of a particular population found to be affected by a medical condition (typically a disease or a risk factor such as smoking). It is derived by comparing the number of people found to have the condition with the total number of people studied, and is usually expressed as a fraction, as a percentage, or as the number of cases per 10,000 or 100,000 people. It is the total number of cases of a disease in a given area during a given time period

Meta-analysis: A statistical procedure for combining data from multiple studies. When the treatment effect (or effect size) is consistent from one study to the next, meta-analysis can be used to identify this common effect. The effect may be summarised as a meta-estimate of relative risk (meta-RR).

MOOSE (Meta-analyses Of Observational Studies in Epidemiology): a checklist which contains specifications for reporting of meta-analyses of observational studies in epidemiology.

JEM: Job exposure matrix is a tool used to assess exposure to potential health hazards in occupational epidemiological studies. Essentially, a JEM comprises a list of levels of exposure to a variety of harmful (or potentially harmful) agents for selected occupational titles.

Risk: The probability that an event will occur (e.g., that an individual will develop disease within a stated period of time or by a certain age).

Incidence rate or incidence: The rate of occurrence of a new event of interest (e.g. cancer) in a given population over a given time period. (The rate is often expressed in terms of cases per year of 'person-time', and so incorporates the numbers at risk of the event, the time for which they are at risk and the numbers that go on to develop that event.)

Standardised Incidence Ratio (SIR) is used to determine if the occurrence of cancer in a relatively small population is high or low. An SIR analysis can establish if the number of observed cancer cases in a particular geographic area is higher or lower than expected, given the population and age distribution for that community.

Confidence Interval (CI): The Relative Risk reported in a study is only an estimate of the true value of relative risk in the underlying population; a different sample may give a somewhat different estimate. The CI defines a plausible range in which the true population value lies, given the extent of statistical uncertainty in the data. The commonly chosen 95% CIs give a range in which there is a 95% chance that the true value will be found (in the absence of bias and confounding). Small studies generate much uncertainty and a wide range, whereas very large studies provide a narrower band of compatible values.

Cox proportional-hazards model (Cox, 1972) is a regression model commonly used statistical in medical research for investigating the association between the survival time of patients and one or more predictor variables.

Bias: A systematic tendency to over- or under-estimate the size of a measure of interest in a study.

Confounding: Arises when the association between exposure and disease is explained in whole or part by a third factor (confounder), itself a cause of the disease that occurs to a different extent in the groups being compared

References

Ahn, Y. S. and K. S. Jeong (2015). "Mortality due to malignant and non-malignant diseases in Korean professional emergency responders." PLoS One **10**(3): e0120305.

Ahn, Y. S., K. S. Jeong and K. S. Kim (2012). "Cancer morbidity of professional emergency responders in Korea." Am J Ind Med **55**(9): 768-778.

Alexander, B.M.; Baxter, C.S. Flame-retardant contamination of firefighter personal protective clothing - A potential health risk for firefighters. *J Occup Environ Hyg* **2016**, *13*, D148-155.

Amadeo, B., J. L. Marchand, F. Moisan, S. Donnadieu, C. Gaelle, M. P. Simone, C. Lembeye, E. Imbernon and P. Brochard (2015). "French firefighter mortality: analysis over a 30-year period." Am J Ind Med **58**(4): 437-443.

Austin, C. C., D. Wang, D. J. Ecobichon and G. Dussault (2001). "Characterization of volatile organic compounds in smoke at municipal structural fires." J Toxicol Environ Health A **63**(6): 437-458.

Baris D, Garrity TJ, Telles JL et al. Cohort mortality study of Philadelphia firefighters. *Am J Ind Med* 2001 39:463–476

Bates MN (2007). Registry-based case-control study of cancer in California firefighters. *Am J Ind Med*, 50:339–344.

Bigert C, Martinsen JI, Gustavvson P, Sparen P. Cancer incidence among Swedish firefighters: an extended follow-up of the NOCCA study. Int Arch Occup Environ Hlth 2020 93:197–204.

Bott, R.C.; Kirk, K.M.; Logan, M.B.; Reid, D.A. Diesel particulate matter and polycyclic aromatic hydrocarbons in fire stations. *Environ Sci Process Impacts* **2017**, *19*, 1320-1326.

Brantom PG, Brown I, Baril M, McNamee R. Epidemiological literature review on the risk of cancer among firefighters. Institut de recherche Robert-Sauvé en santé (IRSST) Quebec 2018

Casjens S, Bruning T, Taeger D. Re: Cancer incidence and mortality among firefighters. Int. J. Cancer 2019; 145: 1701.

Casjens S, Bruning T, Taeger D. Cancer risks of firefighters: a systematic review and meta-analysis of secular trends and region-specific differences. Int Arch Occup Environ Hlth 2020; 93(7):839-852.

Daniels RD, Kubale TL, Yiin JH et al, Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950-2009). Occup Environ Med 2014 **71**(6): 388-397.

Daniels RD, Bertke S, Dahm MM et al Exposure-response relationships for select cancer and non-cancer health outcomes in a cohort of U.S. firefighters from San Francisco, Chicago and Philadelphia (1950-2009) Occup Environ Med 2015 **72**(10): 699-706.

Engelsman, M.; Snoek, M.F.; Banks, A.P.W.; Cantrell, P.; Wang, X.; Toms, L.M.; Koppel, D.J. Exposure to metals and semivolatile organic compounds in Australian fire stations. *Environ Res* **2019**, *179*

Fent, K.W.; Eisenberg, J.; Snawder, J.; Sammons, D.; Pleil, J.D.; Stiegel, M.A.; Mueller, C.; Horn, G.P.; Dalton, J. Systemic exposure to PAHs and benzene in firefighters suppressing controlled structure fires. *Ann Occup Hyg* **2014**, *58*, 830-845.

Fernando, S.; Shaw, L.; Shaw, D.; Gallea, M.; VandenEnden, L.; House, R.; Verma, D.K.; Britz-McKibbin, P.; McCarry, B.E. Evaluation of Firefighter Exposure to Wood Smoke during Training Exercises at Burn Houses. *Environ Sci Technol* **2016**, *50*, 1536-1543.

Glass DC, Pircher S, Del Monaco A, Hoorn SV, Sim MR. Mortality and cancer incidence in a cohort of male paid Australian firefighters. Occup Environ Med 2016;73:761–771.

Glass DC, Del Monaco A, Pircher S, Hoorn SV, Sim MR. Mortality and cancer incidence in a cohort of male volunteer Australian firefighters. Occup Environ Med 2017,74, 628-638.

Glass DC, Pircher S, Del Monaco A, Hoorn SV, Sim MR. Mortality and cancer incidence in a cohort of female Australian firefighters. Occup Environ Med 2019;76:215-221.

Grace K. McMasters GK, Genaidy AM, Succop P, Deddens J, Sobeih T, Barriera-Viruet H, Dunning K, Lockey J. Cancer risk among firefighters: a review and meta-analysis of 32 studies. J Occ Environ Med 2006 48 (11):1189-1202

Graveling RA, Crawford JO. Occupational health risks in firefighters. Institute of Occupational Medicine. Strategic Consulting Report: P530. 2010.

Harris MA, Kirkham TL, MacLeod JS et al. Surveillance of cancer risks for firefighters, police, and armed forces among men in a Canadian census cohort. Am J Ind Med. 2018;61:815–823.

IARC (2010) IARC Monographs on the evaluation of carcinogenic risks to humans: Painting, firefighting and shift work. Volume 98 International Agency for Research on Cancer, Lyon

Ide, C. W. (2014). "Cancer incidence and mortality in serving whole-time Scottish firefighters 1984-2005." Occup Med (Lond) **64**(6): 421-427.

IIAC (2008) Testicular cancer in firefighters. Position paper number 21. 2008

IIAC (2010) Information Note. IIAC Commissioned Reviews 2010 – Occupational Health in Fire-fighters 2010

Jalilian H, Ziaei M, Weiderpass E et al. Cancer incidence and mortality among firefighters. Int. J. Cancer 2019; 145: 2639–2646

Langevin SM, Eliot M, Butler RA et al. Firefighter occupation is associated with increased risk for laryngeal and hypopharyngeal squamous cell carcinoma among men from the Greater Boston area. Occup Environ Med 2020;**77**:381–385.

Lee DJ, Koru-Sengul T, Hernandez MN et al. Cancer risk among career male and female Florida firefighters: Evidence from the Florida Firefighter Cancer Registry (1981-2014) Am J Ind Med. 2020;63:285–299.

Ma F, Fleming LE, Lee DJ et al. (2006). Cancer incidence in Florida professional firefighters, 1981 to 1999. *J Occup Environ Med* 48:883–888.

McMasters GK, Genaidy AM, Succop P et al. Cancer risk among firefighters: A review and meta-analysis of 32 Studies. JOEM 2006 48(1): 1189-1202.

Mehlum IS, Johannessen HA, Kjærheim K, Grimsrud TK, Nordby KC. Risk of prostate cancer in firefighters: A review and meta-analysis of studies published after 2007. European Journal of Public Health 2018, 28 Supplement 4, 152.

Paget-Bailly, S., F. Guida, M. Carton, G. Menvielle, L. Radoi, D. Cyr, A. Schmaus, S. Cenee, A. Papadopoulos, J. Fevotte, C. Pilorget, M. Velten, A. V. Guizard, I. Stucker and D. Luce (2013). "Occupation and head and neck cancer risk in men: results from the ICARE study, a French population-based case-control study." J Occup Environ Med **55**(9): 1065-1073.

Pedersen, J.E.; Petersen, K.U.; Hansen, J. Historical changes in chemical exposures encountered by Danish firefighters. *Scand J Work Environ Health* **2019**, *45*, 248-255.

Pinkerton L, Bertke SJ, Yiin J et al. Mortality in a cohort of US firefighters from San Francisco, Chicago and Philadelphia: an update Occup Environ Med 2020;**77**:84–93

Pukkala, E., J. I. Martinsen, E. Weiderpass, K. Kjaerheim, E. Lynge, L. Tryggvadottir, P. Sparen and P. A. Demers (2014). Cancer incidence among firefighters: 45 years of follow-up in five Nordic countries. Occup Environ Med 71(6): 398-404.

Roelofs, C. R., G. J. Kernan, L. K. Davis, R. W. Clapp and P. R. Hunt (2013). "Mesothelioma and employment in massachusetts: analysis of cancer registry data 1988-2003." Am J Ind Med 56(9): 985-992.

Soteriades E, Kim J, Christophi CA, Kales N. Cancer Incidence and Mortality in Firefighters: A State-of-the-Art Review and Meta-Analysis. Asian Pacific Journal of Cancer Prevention, 2019;20: DOI:10.31557

Sritharan J, Pahwa M, Demers PA et al. Prostate cancer in firefighting and police work: a systematic review and metaanalysis of epidemiologic studies Environmental Health 2017;16:124

Sjostrom, M.; Julander, A.; Strandberg, B.; Lewne, M.; Bigert, C. Airborne and Dermal Exposure to Polycyclic Aromatic Hydrocarbons, Volatile Organic Compounds, and Particles among Firefighters and Police Investigators. *Ann Work Expo Health* **2019**, *63*, 533-545

Stec, A.A.; Dickens, K.E.; Salden, M.; Hewitt, F.E.; Watts, D.P.; Houldsworth, P.E.; Martin, F.L. Occupational Exposure to Polycyclic Aromatic Hydrocarbons and Elevated Cancer Incidence in Firefighters. *Scientific Reports* **2018**, 1-8.

Stec, A.A.; Dickens, K.E.; Salden, M.; Hewitt, F.E.; Watts, D.P.; Houldsworth, P.E.; Martin, F.L. Occupational Exposure to Polycyclic Aromatic Hydrocarbons and Elevated Cancer Incidence in Firefighters. *Scientific Reports* **2018**, 1-8.

Tsai, R. J., S. E. Luckhaupt, P. Schumacher, R. D. Cress, D. M. Deapen and G. M. Calvert (2015). "Risk of cancer among firefighters in California, 1988-2007." Am J Ind Med **58**(7): 715-729.

Youakim S. Risk of cancer among firefighters, a quantitative review of selected malignancies. Arch Environ Occ Hlth 2006:61(5);223-231.

Zhao G, Erazo B, Ronda E et al. Mortality Among Firefighters in Spain: 10 Years of

Follow-up. Ann Work Expo Health 2020 64(6):614-621.

Report Published: February 2021