Firefighters and cancer: the epidemiological evidence

Joanne O. Crawford, Thomas Winski, Damien McElvenny, Richard Graveling, Ken Dixon
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It is recognised that firefighters can be exposed to many different harmful substances. In 2007 the International Agency for Research on Cancer convened a working group to assess the carcinogenicity of a variety of occupations, increased rates of testicular, prostate and non-Hodgkin’s lymphoma were identified for firefighting. This report examines the research published since an IOM review for the UK Industrial Injuries Advisory Council, by carrying out a systematic review and meta-analyses of the epidemiological evidence for specific cancers in firefighters. In total 304 publications were screened against the inclusion criteria, 261 publications were excluded based on their title/abstract and a further 20 were excluded once the full publication had been examined. The remaining 23 papers were included in the review. Meta-analyses were carried out for 23 specific cancer sites. Cancers identified as having a positive association with firefighting included colon (meta-RR=1.18, 95% CI 1.08-1.29), rectal (meta-RR=1.16, 95% CI 1.05-1.29), lymphatic and haematopoietic (meta-RR=1.20, 95% CI 1.07-1.35), non-Hodgkin’s lymphoma (meta-RR=1.14, 95% CI 1.05-1.23), melanoma (meta-RR=1.41, 95% CI 1.21-1.65), prostate (meta-RR=1.13, 95% CI 1.03-1.24), bladder (meta-RR=1.12, 95% CI 1.01-1.26) and kidney cancer (meta-RR=1.16, 95% CI 1.00-1.23). The report highlights that a number of cancers were identified as having a raised risk among firefighters, but there was no evidence in this literature of the association found previously with testicular cancer.
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SUMMARY

It is recognised that firefighters are exposed to a variety of harmful substances and physical agents, and there has been a growing body of research in the last decade in relation to cancer occurrence within this occupational group. In 2007 the International Agency for Research on Cancer (IARC) convened a working group to assess the carcinogenicity of a variety of occupations including firefighting. This working group identified increased risks for three types of cancer, testicular, prostate and non-Hodgkin’s lymphoma. Exposure assessment for this group has been difficult, including the reliable quantification of exposure. This report is of a study examining the research published since a 2010 review carried out for the Industrial Injuries Advisory Council, by carrying out a systematic review and meta-analyses of the epidemiological evidence for specific cancers in firefighters.

The first stage of the research was the development of a search strategy and carrying out searches between April and May 2016. In total 304 publications were screened against the inclusion criteria and 261 publications were excluded. From the 43 full publications sourced, eighteen were excluded as not being relevant to the review and two duplicate papers were identified. The resulting 23 papers were included in the review.

Meta-analyses were carried out for 23 specific cancer sites. Cancers identified as having a positive association included colon (meta-RR=1.18, 95% CI 1.08-1.29), rectal (meta-RR=1.16, 95% CI 1.05-1.29), lymphatic and haematopoietic (meta-RR=1.20, 95% CI 1.07-1.35), non-Hodgkin’s lymphoma (meta-RR=1.14, 95% CI 1.05-1.23), melanoma (meta-RR=1.41, 95% CI 1.21-1.65), prostate (meta-RR=1.13, 95% CI 1.03-1.24), bladder (meta-RR=1.12, 95% CI 1.01-1.26) and kidney cancer (meta-RR=1.16, 95% CI 1.00-1.23).

Firefighters are exposed to a large number of hazards and the types of exposure depend on what is being combusted or which chemical has been spilled. While positive associations have been identified in one country, this has not necessarily been reflected internationally. There can be many explanations for this, including variations in risk amongst the comparator population and differences in hazard exposures between firefighters in different countries reflecting different firefighting strategies. While exposure assessment has been difficult in this area of research, reliably quantifying exposure is also difficult. Data from other comparable groups were not of a high enough quality to allow a reasonable comparison.

The report identifies firefighters as having an elevated risk of a number of cancers compared to the general population. However, the analysis of data for testicular cancer did not affirm the increased risk identified by some earlier analyses.
1 INTRODUCTION

It is recognised that firefighters are potentially exposed to a variety of harmful substances and physical agents, and there has been a growing body of research in the last decade in relation to cancer occurrence within this occupational group.

In 2007, the International Agency for Research on Cancer (IARC) convened a working group to assess the carcinogenicity of a variety of occupations, including firefighting. From this, a summary publication (Straif et al., 2007, IARC 2007) indicated that firefighters are exposed to many toxic combustion products, including many known, probable or possible carcinogens. As part of their deliberations, the working group updated the meta-analysis of LeMasters et al., (2006), concluding that, although consistent patterns were difficult to discern (probably due to the wide variability in exposure between different firefighter populations in different countries), they were satisfied that for three types of cancer the relative risks were consistently and significantly increased. Thus, for testicular cancer all six studies identified showed increased risks (average relative risk [ARR] 1.5); for prostate cancer 18 of 21 studies showed increased risks (ARR 1.3); and, for non-Hodgkin’s lymphoma increased risks were identified in five of six studies (ARR 1.2) (Straif et al., 2007).

While exposure assessment has been difficult within this area of research, there has also been considerable difficulty in reliably quantifying those exposures. It was additionally noted that the acute and chronic inflammatory respiratory effects found in firefighters would provide a plausible mechanism for respiratory carcinogenesis. The IARC working group concluded by classifying occupational exposure as a firefighter as “possibly carcinogenic to humans” (Group 2B).

Other epidemiological evidence has since emerged which appears to strengthen the apparent connection between working as a firefighter and some forms of cancer. For example, Kang et al (2008) reported increased Standardised Morbidity Odds Ratios (SMORs) for colon cancer (SMOR = 1.36, 95% CI: 1.04–1.79), and brain cancer (SMOR = 1.90, 95% CI: 1.10–3.26). The authors also reported weaker evidence of increased risk for bladder cancer (SMOR = 1.22, 95% CI: 0.89–1.69), kidney cancer (SMOR = 1.34, 95% CI: 0.90–2.01), and Hodgkin’s lymphoma (SMOR = 1.81, 95% CI: 0.72–4.53) from a total of 24 cancers studied.

In 2010, Graveling and Crawford published a review for the UK Industrial Injuries Advisory Council (IIAC) on Occupational Health Risks in Firefighters (Graveling and Crawford, 2010). This review examined 23 cancers and examined the relative risk of each of the cancers in relation to the occupation of firefighter. The remit of this particular review was to identify whether there was robust evidence for at least a doubling of risk within the firefighter population in relation to particular cancers, as any such cancer could then be recommended for classification as a prescribed industrial disease within the UK. Although a doubling of risk was not identified in any of the 23 cancers examined, estimated risks relative to the general population based on the cumulative evidence for colon, skin, prostate, testicular and breast cancer were higher than 1.0.

While the risks to firefighters have been previously examined, these should be put this into context within the general population. As an occupation, firefighters require specific fitness standards to be achieved on entry and in some countries throughout their working life. Furthermore, firefighters often have additional health screening throughout their working lives. This has led to suggestions of a “healthy worker survivor effect” where chronic diseases in older age are less likely to occur in firefighters compared to the general population. For example, a Canadian study found a decrease in risk of strokes (% less likely) or diabetes (28% less likely)
amongst firefighters while some risks were increased such as colon cancer (31% more likely) or kidney cancer (29% more likely). (Dow et al 2015).

It is recognised that firefighters are exposed to certain types of environments during firefighting and overhaul (cleaning up). These environments include different types of fires including buildings or forest fires as well as dealing with motor vehicle accidents and extrication of people from cars. Several of these tasks are known to cause exposure to substances hazardous to health; although PPE and RPE are provided in much of cases. However, when examining all-cause mortality of different occupational groups, Harris et al (2016) found in the UK that there was a 25% reduction in the number of deaths from all causes in fire service personnel between 1979 and 2010 in England and Wales. This reduction may be due to improved safety, but it may also reflect reductions in the numbers of men employed in firefighting, and falling mortality from some diseases across the whole population.

The data used in previous studies of cancer and firefighting typically used the general population as the comparator when analysing the incidence data from cancer registries or mortality data including cancer mortality from national death registries. Thus, where an increase or decrease is identified within the firefighting population, this is in comparison to what would be expected within the general population.

### Table 1 Lifetime risk of specific cancers in the general population (UK data for 2012)

<table>
<thead>
<tr>
<th>Cancer</th>
<th>Lifetime risk (Female)</th>
<th>Lifetime risk (Male)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melanoma</td>
<td>1.85%</td>
<td>1.94%</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.95%</td>
<td>2.62%</td>
</tr>
<tr>
<td>Brain</td>
<td>1.37%</td>
<td>1.35%</td>
</tr>
<tr>
<td>Breast</td>
<td>12.99%</td>
<td>0.12%</td>
</tr>
<tr>
<td>Bowel</td>
<td>5.47%</td>
<td>7.27%</td>
</tr>
<tr>
<td>Kidney</td>
<td>1.15%</td>
<td>1.96%</td>
</tr>
<tr>
<td>Leukaemia</td>
<td>1.07%</td>
<td>1.61%</td>
</tr>
<tr>
<td>Lung</td>
<td>6.17%</td>
<td>7.76%</td>
</tr>
<tr>
<td>Myeloma</td>
<td>0.66%</td>
<td>0.89%</td>
</tr>
<tr>
<td>NHL</td>
<td>1.73%</td>
<td>2.12%</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>0.90%</td>
<td>1.85%</td>
</tr>
<tr>
<td>Pancreas</td>
<td>1.38%</td>
<td>1.44%</td>
</tr>
<tr>
<td>Prostate</td>
<td>13.72%</td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>0.76%</td>
<td>1.51%</td>
</tr>
</tbody>
</table>


Table 1 presents the lifetime risk of getting a particular cancer in individuals in the UK general population. However, an individual’s cancer risk is dependent on several factors including genetic make-up, age, and exposure to carcinogens; but also including lifestyle factors such as smoking and diet. For example, the risk of lung cancer among individuals who smoke tobacco is 15.9% in males and 9.5% for women. Comparing that to Table 1, which includes both smokers and non-smokers, it means that lung cancer risks in non-smokers are much lower than the risks presented of 6.2% and 7.8%. Previous research in firefighters has identified that there is not an excess risk of lung cancer in firefighters; this is potentially due to the protection afforded by consistent use of breathing apparatus and other PPE. By using PPE, firefighters will not come into contact with chemicals, dust and fumes to the same extent as they might otherwise do without the use of PPE. Nevertheless, surrogates for cumulative exposure such as duration of employment can be used to provide indications of risk in relation to cumulative exposure to work as a fire-fighter. Rather the evidence has to be examined in relation to known
exposures but in the context of the use of protective equipment among a group of healthy individuals where risk of specific cancer may be reduced because of these factors.

Other important factors, which are difficult to take into account, are the long latency period for many cancers and the implicit assumption that exposure to risk as a firefighter has remained constant throughout that time. This assumption is not necessarily valid. In many countries, the protection worn by firefighters (including the more routine use of BA and fire hoods) has improved considerably over a period of about 30 years, which will have reduced the extent of exposure to hazardous materials. However, to offset this, the nature of fires in terms of the substances burning and consequent exposures to potentially toxic combustion products will also have changed, with an increase in the use of plastics and other man-made materials.

The aim of the following report is to examine the research published since the 2010 review for IIAC, by carrying out a systematic review of publications since that date on the epidemiological evidence for specific cancers in firefighters.
2 METHODOLOGY

The research question addressed by the review is:

1. What is the epidemiological evidence of the incidence of or mortality from specific cancers in firefighters, and how does this compare to other relevant groups.

A search strategy was developed and is available in Appendix 1. Searches were carried out between April and May 2016.

In total, 304 reference sources were identified from the searches. The title and abstract (where available) for the reference sources were screened against the inclusion criteria (listed in Appendix 1). This resulted in the exclusion of 261 papers which did not fit the inclusion criteria.

The next stage of evaluation for the papers was completed after receipt of the full papers. From the 43 papers, eight were excluded as not fitting the inclusion criteria. The papers and the reasons for exclusion are presented in Appendix 2. Two duplicate papers were identified and eight papers were identified as being relevant to two additional research questions being addressed in future work.

For those 25 papers included, 23 examined firefighters and two were on police and criminal investigators (these were subsequently excluded). The papers included for firefighters comprised three case-control studies, 12 cohort studies, two systematic reviews, five reviews and one opinion/editorial. The papers are summarised in Appendix 3.

Meta-analysis was carried out using the statistical package Stata (Statcorp, 2013). Fixed effect analyses were carried out in the absence of statistically significant heterogeneity and random effects analyses when significant heterogeneity was present (DerSimonian & Laird 1986)

We are aware that the main reason for carrying out a meta-analysis is to explore heterogeneity of study results (e.g. Greeland 1987) in order to understand why different studies might be producing different results. Meta-analyses should contain sensitivity analyses to assess the robustness of any findings and should also contain an assessment of the risk of bias. Further exploration of these issues and other expected aspects of meta-analysis during a later phase of this work.
RESULTS

3.1 CANCER OVERALL

Several papers calculated the risk of cancer among firefighters as an occupation and the incidence of all cancers combined in this group. Daniels et al., (2013) identified a standardised incidence ratio (SIR) compared to the general population of 1.09, 95% CI 1.06-1.12 for all forms of cancer in US firefighters. Glass, (2009), when researching Australian firefighters identified an SIR=1, 95% CI 0.87-1.15, and Pukkala et al., (2014) in their study of Nordic firefighters identified an SIR=1.1, 95% CI 1.02-1.11, again in each case for all forms of cancer.

Zeig-Owens et al., (2011) carried out analysis post 9/11 for the World Trade Center exposed firefighters and found that the SIR for all cancers =1.1, 95% CI 0.98-1.25 any form of cancer amongst those exposed during the rescue and recovery on the 11th of September 2001. Yip et al., (2005) identified a cumulative incidence of cancer of 3.1% after 12 years among firefighters and emergency service workers who had attended the World Trade Centre. This gives a mixed picture internationally in relation to cancer incidence among firefighters compared to the general population.

Mortality rates have also been examined, two studies from Korea, (Ahn et al., 2012, Ahn and Jeong, 2015), identified standardised mortality ratio (SMR) of 0.97, 95% CI 0.88-1.06 and 0.58, 95% CI 0.50-0.68 compared to the population. Ide (2014) carried out a cohort study of Scottish firefighters using reference populations from Scotland and the West of Scotland. The paper identified that for all cancers, the incidence in firefighters was significantly lower than both the reference groups (p<0.001). The incidence rate for all cancers among firefighters was 86.5 cases per 100,000 in firefighters versus the reference populations of Scotland (123.7 per 100,000) and the West of Scotland (337.0 per 100,000).

These data suggest there are mixed results in relation to overall cancer incidence and mortality rates among firefighters and some evidence of a reduced risk of cancer mortality among firefighters. It is not possible to determine whether these differences reflect any substantive trend or national differences in risk. However, a clearer more complex picture can be obtained when examining specific cancer sites for firefighters

3.2 SPECIFIC CANCERS

The review by Graveling and Crawford, (2010) examined 23 different cancers. As this work is one of the most recent systematic reviews with regard to cancer and firefighters, it has been used as starting point when examining research carried out since 2009.

A decision was made to analyse the results of the papers pre and post 2000. The aim of this was to look at any crude changes in the levels of reported relative risks over time and used 2000 as an arbitrary cut-off date representing an approximate median year of publication. However, it should be noted that some of the cohorts have included firefighters from 1925 through to 2011 and it is self-evident that working practices as well as protective equipment have changed since the 1920s. The split by publication date should therefore not be interpreted as representing data collected pre and post 2000.

3.2.1 Lip, oral (buccal) cavity and pharynx

The review by Graveling and Crawford (2010) identified an estimated risk relative to the general population of between 1 and 1.1. Since this review, one further cohort study has been published. Pukkala et al., (2014) calculated cancer incidence in Nordic firefighters with an
overall incidence rate of 0.8, 95% CI 0.4-1.3 for this cancer group. The research by Pukkala also examined in further detail cancer of the pharynx (SIR=1, 95% CI 0.6-1.7), cancer of the lip (SIR=0.8, 95% CI 0.46-1.28), cancer of the tongue (SIR=1.04, 95% CI 0.52-1.87) and cancer of the salivary glands (SIR=1.69, 95% CI 0.40-1.43).

Two case-control studies also examined cancer of the oral cavity. Tsai et al., (2015) examined cancer in Californian firefighters. The analysis identified that the odds ratio of being a firefighter was OR=1.44, 95% CI 0.89-2.33 compared to individuals with four specified control cancers unlikely to be associated with firefighting. Further results examined cancer of the tongue (OR=1.18, 95% CI 0.82-1.70), cancer of the salivary glands (OR=1.30, 95% CI 0.75-2.25), cancer of the pharynx (OR=1.06, 95% CI 0.75-1.50) and cancer of the gum and mouth (OR=1.07, 95% CI 0.62-1.85). The second study was Paget-Bailly et al., (2013) as part of the French ICARE population based research project. The study included 2415 cases of head and neck cancer versus a control group of 3555 controls. There were 13 firefighters within the cases and 12 within the control group. The odds ratio of being a firefighter for those who had head and neck cancer compared with the general population was calculated as 3.90, 95% CI 1.40-11.20.

The majority of studies do not show an increased risk of head or neck cancer amongst firefighters with the exception of one study from a French working population. However, although difficult to elucidate the precise explanation for this apparent anomaly it is noted that, according to the authors, in this study cases were greater consumers of alcohol and tobacco than controls, suggesting that any apparent excess may not be attributable to their occupation as firefighters.

Due to the differences in types of cancers included in the research, a meta-analysis of the data was not performed.

### 3.2.2 Oesophageal cancer

The review of oesophageal cancer by Graveling and Crawford (2010) gave an estimated risk relative to the general population of between 1.10 to 1.20. However, in the meta-analyses by LeMasters et al., (2006), the meta-relative risk was calculated as 2.03, 95% CI 1.05-3.57 indicating a positive association.

Since that date, four further cohort studies have been published that examined incidence rates in firefighters. Ahn et al., (2012) analysed data from male professional emergency responders in Korea. As part of the analysis, a sub-set of firefighters (n=29453) was included. The analysis identified an SIR for oesophageal cancer for the firefighters of 0.75, 95% CI 0.28-1.64. The US study by Daniels et al., (2013) identified an SIR=1.62, 95% CI, 1.31-2.00; with Pukkala et al., (2014) calculating an SIR=0.98, 95% CI 0.28-1.64. Zeig-Owens et al., (2011), compared exposed and non-exposed firefighters who attended the World Trade Centre, with exposed being those exposed to dust from the World Trade Centre collapse. This study identified an SIR of 1.32, 95% CI 0.12-14.53.

The one case-control study included in this review identified that compared to individuals with four specified control cancers unlikely to be associated with firefighting odds ratios of OR=8.89, 95% CI 0.89-2.33 in Californian firefighters (Tsai et al., 2015).

Again, these data show a mixed picture of results in relation to associations between firefighting and oesophageal cancer increased incidence of cancer in the United States studies than in one study in Korea and one in Europe.
To examine these data in more detail, a meta-analysis of studies which included rates of oesophageal cancer was carried out. The analysis included data from the Graveling and Crawford (2010) review and the papers analysed there (Aronson et al., 1994, Beaumont et al., 1991, Demers et al., 1994, Kang et al., 2008, Ma et al., 2006, Vena et al., 1987). The meta-analysis identified that using the fixed effect model, a meta-RR=1.25, 95% CI 1.12-1.40 was found in the presence of significant heterogeneity (p<0.001). Using a random effects model, the meta-RR=1.09 95% CI 0.84-1.43.

Comparison was made between papers published pre 2000 and post 2000 to examine trends over reporting periods. This is presented in Figure 1. For studies published before 2000 a meta-RR= 1.48, 95% CI 0.87-2.53 was calculated versus a meta-RR=1.03 95% CI 0.76-1.40 (P=0.351) for studies published in 2000 or later. There is some indication that the RR was lower in more recent studies, but the difference was not significant. Overall there is no evidence that oesophageal cancer risk is increased in fire-fighters.

![Figure 1 Forest Plot for Oesophageal Cancer Paper Published Pre 2000 and Post 2000](image)

### 3.2.3 Stomach Cancer

The review by Graveling and Crawford (2010) calculated an estimated risk relative to the general population for stomach cancer as being close to 1. In updating this review, the cohort studies included both standardised incidence ratios (SIR) and standardised mortality rates

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1 Minor discrepancies in numbers between the plot and the report are due to rounding
(SMR) both of which attempt to estimate relative risk. For stomach cancer, the following ratios were identified, an SIR=1.09, 95% CI 0.91-1.3 (Pukkala et al., 2014), an SMR=0.63, 95% CI 0.43-0.88 (Ahn and Jeong, 2015) and an SIR=1.82, 95% CI 0.44-7.49 (Zeig-Owens et al., 2011). In their case-control study, Tsai et al., (2015) did not show a significant difference in cancer incidence between cases and controls with a calculated incident rate of OR=0.81, 95% CI 0.59-1.11.

The data included do not appear to show an association between stomach cancer and firefighting. However, to examine these data further, a meta-analysis was carried out including the papers by Aronson et al., 1994, Bares et al., 2001, Bates, 2007, Beaumont et al., 1991, Demers et al., 1994, Donnan, 1996, Kang et al., 2008b, Koepp et al., 2013, Ma et al., 2006, Tornling et al., 1994, Vena and Fiedler, 1987.

The meta-analysis for fixed effects identified a meta-RR=0.95 95% CI 0.86-1.05; the meta-RR=0.93 95% CI 0.78-1.12 for the random effects model. Neither therefore showed a positive association between stomach cancer and firefighting.

When comparing studies published before 2000 versus those published post 2000, the meta-analysis calculated a meta-RR=1.09, 95% CI 0.75-1.61 for those published pre 2000 and meta-RR=0.85 95% CI 0.72-1.02 post 2000; neither of which show a significant association. These data are presented in Figure 2 below.

![Figure 2 Forest Plot for Stomach Cancer pre 2000 and post 2000](image-url)
3.2.4 Colon Cancer

From the 2010 review, thirteen papers were included that examined colon cancer and this resulted in an estimated risk relative to the general population of 1.2 (Graveling and Crawford, 2010). In the meta-analyses by LeMasters et al., (2006) an association was found with a summary risk estimate of 1.21, 95% CI 1.03-1.41. Since that review, five cohort studies have been published internationally, none of which showed an association between colon cancer and firefighter as an occupation. These included the research by (Fang et al., 2011), in a Canadian population based case-control study of colon cancer where the odds ratio for those who had colon cancer was calculated at OR=1.83, 95% CI 0.17-0.78. Glass, (2009), calculated a standardised incidence ratio of 0.92, 95% CI 0.61-1.40 in Australian firefighters and Pukkala et al., (2014), calculated an SIR=1.14, 95% CI 0.99-1.31 in Nordic firefighters. Data from Korea identified a standardised mortality ratio of 0.65, 95% CI 0.34-1.40 (Ahn and Jeong, 2015). The paper by Ide, (2014), examined cancer in Scottish firefighters between 1985 and 2004. He identified that for colon cancer, there were significantly lower incidence within the firefighting group (9.1 cases per 100,000) compared to 13.8 cases per 100,000 in the reference population (p<0.01). Finally, Zeig-Owens et al., (2011) calculated an SIR= 1.5, 95% CI 0.69-3.27 in the World Trade Center firefighters.

The one case-control study included in this study identified a similar pattern where risk estimates by Tsai et al., (2015), resulted in an OR=1.1, 95% CI 0.93-1.3 for firefighters compared to individuals with four specified control cancers unlikely to be associated with firefighting.

In comparing the results within these papers, it should be noted that different definitions were with some papers analysing colon cancer and others analysing colorectal cancer.

To examine the reported rates of colon cancer, a meta-analysis was carried out using data from the current papers cited as well as those from the 2010 review Aronson et al., 1994, Baris et al., 2001, Bates et al., 2001, Demers et al., 1994, Grimes et al., 1991, Ma et al., 2006, Sama et al., 1990, Tornling et al., 1994, Vena and Fiedler, 1987.

As noted above, the studies included rates reported as both colon cancer and colorectal cancer. The meta-analysis therefore combined colon, colorectal and rectal cancer. The fixed effect meta-RR for colon, colorectal and rectal cancer combined was equal to 1.14, 95% CI 1.08-1.20 (p=0.168 for heterogeneity).

When comparing studies published pre and post 2000, the fixed effect meta-RR=1.33, 95% CI 1.15-1.55 for studies published before 2000 and meta-RR=1.11, 95% CI 1.05-1.18 for studies published in 2000 or later. These data suggest an association between these cancers and firefighting. However, the collation of colon and colorectal cancer does limit the results, as it is not possible to determine which specific cancer may be causing the excess.
Figure 3 Forest Plot for Colon, Colorectal and Rectal Cancer for Studies Pre and Post 2000

Due to the possible differences in aetiology between colon and rectal cancer, a further meta-analysis was carried out to examine the cancers individually. These data are presented in Figure 4 below. They reveal that both colon and rectal cancers show a significant association with occupation as a firefighter.
3.2.5 Rectal Cancer

Within the Graveling and Crawford (2010) review, data on rectal cancer was examined and an estimated risk relative to the general population was estimated. Although many of the risk estimates were not statistically significantly different to 1.0, the estimated risk had a relatively modest association of less than 1.3. LeMasters et al., (2006) in their meta-analysis did not find a significant association between rectal cancer and firefighting.

In examining more recent cohort studies, as noted in the previous section, Daniels et al., (2013) identified an SIR of 1.16, 95% CI 0.99-1.36 in US firefighters and Pukkala et al., (2014) identified an SIR=0.99, 95% CI 0.82-1.19 for rectal cancer.

The results identified here from cohort and case-control studies do not show any evidence of a significant association of firefighting with rectal cancer. This is in contrast to earlier studies and
when these studies were all included in the meta-analysis in the previous section, there was a positive and significant association between rectal cancer and occupation.

### 3.2.6 Pancreatic Cancer

The review by Graveling and Crawford (2010) estimated risk relative to the general population and they did not identify any raised risks for pancreatic cancer among firefighters. The meta-analysis by LeMasters et al., (2006) found the same. This pattern has continued with the cohort studies included in this review where no statistically significant associations were identified although the ratios in three of the papers were non-significantly greater than one (Glass, 2009, Pukkala et al., 2014, Zeig-Owens et al., 2011). A similar result was found for the case-control study by (Tsai et al., 2015), where an odds ratio of 1.1 (95% CI 0.83-1.46) was calculated.


For the fixed effects model, a meta-RR=1.03, 95% CI 0.92-1.15 (p=0.829) was calculated.

When comparing publications pre and post 2000, a pre-2000 meta-RR=1.17, 95% CI 0.88-1.56 was calculated pre 2000 and a meta-RR=1.00, 95% CI 0.89-1.13 post 2000. These data suggest that pancreatic cancer rates in firefighters are not higher than the general population.

![Pancreatic Cancer Forest Plot](image)

**Figure 5** Forest Plot of Pancreatic Cancer and Publications before and after 2000.

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2 Minor discrepancies in numbers between the plot and the report are due to rounding
3.2.7 Laryngeal Cancer

In relation to laryngeal cancer, the previous review did not identify a positive association between occupation as a firefighter and cancer of the larynx (Graveling and Crawford 2010). Since that review, one cohort study has examined this cancer with a similar non-significant outcome, SIR=1.06, 95% CI 0.72-1.50 (Pukkala et al., 2014). A retrospective cohort study by Glass (2009) identified an SIR=0.67, 95% CI 0.39-1.15 for cancer of the larynx, trachea, bronchus and lung.


A meta-analysis was prepared from this data and the more recent material. From this, a meta-RR=0.94 95% CI 0.76-1.19 (p=0.005 for heterogeneity) was calculated with a random effects meta-RR=0.94, 95% CI 0.76-1.15; neither of which showed a positive association.

When comparing publications pre and post 2000, a meta-RR=0.87, 95% CI 0.7-1.08 was calculated for studies published before 2000 and a meta-RR=1.60, 95% CI 0.30-9.46 for studies published post 2000; neither of these were statistically significant. The data are presented in Figure 6.

![Forest Plot of Laryngeal Cancer and Publications pre and post 2000](image)

**Figure 6** Forest Plot of Laryngeal Cancer and Publications pre and post 2000
3.2.8 Lung Cancer

In the original review by Graveling and Crawford (2010), nineteen studies were examined and an estimated risk relative to the general population was made but there did not appear to be an excess risk for lung cancer from being a firefighter. Among the more recent publications only one cohort study identified a significant association with an SIR=1.15, 95% CI 1.07-1.24 (Daniels et al., 2013). Ide, (2014) when analysing data from a Scottish firefighter population found that the incidence (6.8 per 100,000) among firefighters was significantly lower than the incident rate within the references sample (17.1 per 100,000; p<0.001).

From the other cohort studies included, Glass, (2009) grouped larynx, tracheal, bronchus and lung cancer in Australian firefighters and identified an SIR=0.67, 95% CI 0.39-1.15. Ahn and Jeong, (2015), calculated an SMR=0.58, 95% CI 0.38-0.84 in Korean firefighters for bronchus and lung cancers. Pukkala et al., (2014), calculated an SIR=0.97, 95% CI 0.87-1.09. Zeig-Owens et al., (2011), in their study of firefighters who had attended the world trade centre collapse, identified an SIR=0.53, 95% CI 0.18-1.54.

One case-control study also examined lung cancer, Tsai et al., (2015) calculated odds ratios for lung and bronchus cancer with a resulting OR=1.08, 95% CI 0.92-1.28 for firefighters compared to individuals with four specified control cancers unlikely to be associated with firefighting.

These data provide no evidence of an association between lung cancer and occupation as a firefighter. A further meta-analysis was carried out to examine this in more detail including data from the 2010 review Aronson et al., 1994, Baris et al., 2001, Bates et al., 2001, Bates, 2007, Beaumont et al., 1991, Burnett et al., 1994, Demers et al., 1994, Donnan, 1996, Giles et al., 1993, Kang et al., 2008b, Ma et al., 2006, Sama et al., 1990, Tornling et al., 1994.

In the meta-analysis for lung cancer a fixed effect meta-RR=1.01, 95% CI 0.97-1.05 (p<0.001 for heterogeneity) was calculated with a random effects meta-RR=0.91, 95% CI 0.82-1.01 identified; neither of which were statistically significant.

To examine trends in time, publications pre and post 2000 were compared and for papers published before 2000, a random effects meta-RR=0.84, 95% CI 0.66-1.07 was found and for publications post 2000, a meta-RR=0.93, 95% CI 0.83-1.05 was identified. The analysis is presented in Figure 7.
3.2.9 Skin Cancer

The incidence of skin cancer was evaluated in the review by Graveling and Crawford (2010) where seventeen papers were selected and an estimated risk relative to the general population was made. The review suggested that there was a positive association between skin cancer and firefighting with an estimated risk of between 1.3 and 1.4.

Since this review Ide, (2014), found that the incidence rate of melanoma was significantly higher in in a Scottish cohort of firefighters (13.6 per 100,000 v 8.1 per 100,000 in the Scottish population (p<0.001)). Among Nordic firefighters, an SIR=1.25, 95% CI 1.03-1.51 was calculated (Pukkala et al., 2014). Glass, (2009), examined skin melanoma in Australian firefighters and calculated an SIR=1.24, 95% CI 0.94-2.62. Although not significant, the increased risk ratio mirrors that of other work. The one case-control study that examined skin melanoma identified an odds ratio of OR=1.75, 95% CI 1.44-2.13 in Californian firefighters compared to individuals with four specified control cancers unlikely to be associated with firefighting (Tsai et al., 2015).

Data were collated from publications included in the previous review and a meta-analysis of the data completed. This resulted in a fixed effects meta-RR=1.39, 95% CI 1.29-1.50 (p=0.001 for heterogeneity). The random effects analysis identified a meta-RR=1.35, 95% CI 1.17-1.56.
The second analysis examined papers published pre-2000 versus those published post 2000 and these data are presented in Figure 9.

Figure 8 Forest Plot of Skin Cancer pre and post 2000
Due to the methods used to describe skin cancer, within the body of research, the data were further separated, where possible, into melanoma and non-melanoma skin cancer. This identified that for melanoma, a meta-RR=1.41, 95% CI 1.21-1.65 was calculated but non-melanoma skin cancer was not found to be significantly associated with employment as a firefighter (meta-RR=1.25, 95% CI 0.30-5.14), although this was based on only two studies, one of which showed a significant positive association between non-melanoma skin cancer and firefighting and one of which showed a significant negative association. (See Figure 9).

### 3.2.10 Prostate Cancer

The review by Graveling and Crawford (2010) examined seventeen papers and an estimated risk relative to the general population was made as 1.2-1.3. Straif et al., (2007) in the review of health risks in firefighters, painters and shift work suggested a risk ratio of 1.3 for prostate cancer in firefighters. In reviewing papers published since this review, four cohort studies identified the following. Daniels et al., (2013) identified an SIR=1.02, 95% CI 0.96-1.08 in Caucasian US firefighters. Glass, (2009) calculated an SIR=0.93, 95% CI 0.66-1.3 in Australian firefighters and Ahn et al., (2012) calculated an SMR=1.32, 95% CI 0.6-2.51 in Korean firefighters. Zeig-Owens et al., (2011) in the cohort of World Trade Center cancers identified an adjusted SIR=0.90, 95% CI 0.62-1.30. The final cohort study in Nordic firefighters identified an SIR=1.13, 95% CI 1.05-1.22 (Pukkala et al., 2014).

From the one case-control study, Tsai et al., (2015), identified a higher than expected level of prostate cancer (OR=1.45, 95% CI 1.25-1.69) in firefighters compared to individuals with four specified control cancers unlikely to be associated with firefighting.
No further papers included prostate cancer in their analysis but there does appear to be an association between prostate cancer and occupation as a firefighter.


For prostate cancer a meta-RR=1.11, 95% CI 1.07-1.15 (p<0.001 for heterogeneity) was calculated. The random effects model calculated a meta-RR=1.13, 95% CI 1.03-1.24. Further analysis examining data pre and post 2000 publications identified a meta-RR=1.09, 95% CI 0.72-1.63 pre 2000 versus meta=RR=1.12, 95% CI 1.03-1.22 post 2000. These results do suggest an association and the data are presented in Figure 10.

**Figure 10** Forest Plot of Prostate Cancer and Publications pre and post 2000

### 3.2.11 Testicular Cancer

Two reviews before 2010 examined testicular cancer in firefighters. The review by Straif *et al.*, (2007) suggested a relative risk of 1.5 for men employed as firefighters. The review by Graveling and Crawford (2010) identified an estimated risk relative to the general population between 1.5 and 8.2 was, but concluded that 1.5 was more likely.

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3 Minor discrepancies in numbers between the plot and the report are due to rounding
Since 2010, further publications have examined testicular cancer among firefighters. Ide, (2014) when analysing a Scottish cohort of firefighters did not find a significant difference between incidence rates in firefighters (9.1 per 100,000) when compared to the Scottish population (7.7 per 100,000). Four cohort studies also examined testicular cancer among firefighters and identified no significant excess incidence among firefighters. These comprised Daniels et al., (2013) (SIR=0.75, 95% CI 0.42, Pukkala et al., (2014) (SIR=0.51, 95% CI 0.23-0.98), Glass, (2009) (SIR=0.84, 95% CI 0.35-2.01) and Zeig-Owens et al., (2011), (SIR=0.56, 95% CI 0.19-4.6). The included case-control study also showed a similar trend with an odds ratio of OR=1.1, 95% CI 0.73-1.66 (Tsai et al., 2015) for firefighters compared to individuals with four specified control cancers unlikely to be associated with firefighting.

These data appear to show a reduction in the relative risks of testicular cancer since 2010. A meta-analysis was carried out including data from included papers in the 2010 review (Aronson et al., 1994, Bates et al., 2001, Bates, 2007, Giles et al., 1993, Kang et al., 2008b, Ma et al., 2006, Stang et al., 2003).

Based on these papers, a fixed effect meta-RR=1.32, 95% CI 1.14-1.53 (p<0.053 for heterogeneity) was calculated and a random effects meta-RR=1.22, 95% CI 0.97-1.55. In comparing studies published before 2000, a random effects meta-RR=1.89, 95% CI 0.66-5.41 was found pre 2000 and post 2000, a meta-RR=1.19, 95% CI 0.93-1.53 was calculated.

![Figure 11 Forest Plot of Testicular Cancer pre and post 2000](image-url)
3.2.12 Bladder

Graveling and Crawford (2010) examined sixteen papers in relation to bladder cancer and estimated risk relative to the general population and calculated a summary risk estimate of 1.25. In examining more recent papers, varied results were obtained with differing levels of significance. Among Scottish firefighters, no significant differences were found between firefighters (4.8 per 100,000) and the reference group (5 per 100,000) (Ide, 2014). Daniels et al., (2013) calculated an SIR=1.11, 95% CI 0.99-1.25 in US Caucasian firefighters. Glass, (2009) examined bladder cancer and identified an SIR=0.40, 95% CI 0.13-1.13 and Pukkala et al., (2014) identified in the Nordic cohort an SIR=1.11, 95% CI 0.96-1.28. The work from the World Trade Center firefighters calculated an SIR=1.28, 95% CI 0.47-3.46. However, Ahn et al., (2012), found a significant association between bladder cancer and firefighters in their study of Korean firefighters (SIR=1.60, 95% CI 1.01-2.56).

From the one case-control study included in the review, Tsai et al., (2015) identified an OR=0.99, 95% CI 0.78-1.26 in Californian firefighters compared to individuals with four specified control cancers unlikely to be associated with firefighting. This again shows a mixed picture for bladder cancer over time.

Further analysis was carried out to examine rates over time and a meta-analysis was prepared including the data from the 2010 study (Aronson et al., 1994, Baris et al., 2001, Bates et al., 2001, Bates, 2007, Demers et al., 1994, Donnan, 1996, Kang et al., 2008b, Ma et al., 2006, Sama et al., 1990, Vena and Fiedler, 1987).

The meta-analysis identified a fixed effect meta-RR=1.09, 95% CI 1.02-1.16 (p=0.019 for heterogeneity) with a meta-RR for random effects equal to 1.12, 95% CI 1.01-1.26. However, it should be noted that two of the risk estimates are based on SMORs which are prone to bias (Stewart & Hunting 1988).

Comparison was made between studies published pre and post 2000. A random effects meta-RR= 1.35, 95% CI 0.88-2.07 was calculated for studies before 2000 and a meta-RR=1.09, 95% CI 0.98-1.22 for studies post 2000. These studies are presented in Figure 12.
The association between kidney cancer and occupation as a firefighter was examined by Graveling and Crawford (2010) who made an estimated risk relative to the general population identified that there was a possible excess risk (approximately 1.1-1.2). Since that review, four cohort studies have examined kidney cancer in firefighters including Daniels et al., (2013), who identified a positive and significant association (SIR=1.27, 95% CI 1.09-1.48). Ide, (2014), found a statistically significantly increased incidence rate among Scottish firefighters of 9.1 per 100,000 compared to 4.4 per 100,000 in the population control group (p<0.001). The final three cohort studies included found varied results; however the study by Glass analysed data including kidney and renal tract (Glass, 2009, Pukkala et al., 2014, Zeig-Owens et al., 2011).

While the results for kidney cancer are not conclusive, a further meta-analysis was carried out using publications from the 2010 review (Aronson et al., 1994, Baris et al., 2001, Bates, 2007, Beaumont et al., 1991, Burnett et al., 1994, Demers et al., 1994, Guidotti, 1993, Kang et al., 2008a, Ma et al., 2006, Tornling et al., 1994, Vena and Fiedler, 1987). The meta-analysis could only include papers where kidney cancer was the defined outcome measure.

The meta-analysis identified that for fixed effect, the meta-RR=1.17, 95% CI 1.08-1.27 (p=0.006 for heterogeneity). The random effects analysis identified a meta-RR=1.16, 95% CI 1.00-1.35. A further analysis was carried out to examine trends between studies published pre and post 2000. For studies published before 2000, meta-RR=1.27, 95% CI 0.87-1.96 and for studies published post 2000, meta-RR=1.11, 95% CI 0.95-1.29.
These data suggest there may be an association between firefighting and kidney cancer and the forest plot is presented in Figure 13.

![Figure 13 Forest Plot of Kidney Cancer and Publications Pre and Post 2000](image)

### 3.2.14 Brain

Brain cancer was examined by Graveling and Crawford (2010) and based on an estimated risk relative to the general population estimated from seventeen papers; a risk estimate of 1.2 was suggested. From the research published since that date, Ide (2014) did not find a significant difference between Scottish firefighters (4.8 per 100,000) and the comparative general population (5 per 100,000).

Four cohort studies published since 2010 have examined brain cancer in firefighters, none of which have found a positive association between brain cancer and being a firefighter (Ahn et al., 2012, Daniels et al., 2013, Pukkala et al., 2014). However, the case-control study by (Tsai et al., 2015), did identify a significant association with an OR=1.54, 95% CI 1.19-2.00 for firefighters compared to individuals with four specified control cancers unlikely to be associated with firefighting.

The fixed-effects meta-RR was 1.17, 95% CI 1.05-1.29 (P=0.002 for heterogeneity) and the random effects meta-RR=1.17, 95% CI 0.97-1.41. A further analysis based on publication date (pre and post 2000) calculated a random effects meta-RR=1.47, 95% CI 1.05-2.06 for studies pre 2000 and meta-RR=1.04, 95% CI 0.83-1.31 for studies published post 2000. These data are presented in Figure 14 and suggest that earlier studies did show a significant association but this is not apparent in the more recent papers.

![Forest Plot of Brain Cancer and Publications pre and post 2000](image)

### 3.2.15 Thyroid

The systematic review by Graveling and Crawford (2010) did not find any consistent evidence in relation to firefighting and thyroid cancer. In more recent studies, the evidence does not show a statistically significant association from three cohort studies including Pukkula et al., (2014) (SIR=1.28, 95% CI 0.75-2.05), Zeig-Owens et al., (2011) (SIR=3.67, 95% CI 0.82-16.42 Corrected Value) and Ahn et al., (2012) (SIR=1, 95% CI 0.6-1.56). The case-control study by Tsai et al., found similar results (OR=1.27, 95% CI 0.88-1.84) for firefighters compared to individuals with four specified control cancers unlikely to be associated with firefighting.

These data do not suggest an association between thyroid cancer and firefighting as an occupation.

### 3.2.16 Lymphatic and Haematopoietic Cancers

The review by Graveling and Crawford (2010) did not find any consistent results in relation to lymphatic and haematopoietic cancers. Inconsistency was found for those studies that examined...
lymphatic and haematopoietic cancers as part of the cohort analysis (Ahn et al., 2012, Ahn and Jeong, 2015).

A meta-analysis was carried out using data from the 2010 review and data from included papers. (Beaumont et al., 1991, Burnett et al., 1994, Demers et al., 1994, Eliopoulos et al., 1984, Grimes et al., 1991, Tornling et al., 1994, Vena and Fiedler, 1987). The fixed effect meta-RR=1.20, 95% CI 1.07-1.35 (p=0.161 for heterogeneity). When examining data published pre and post 2000, the meta-RR was 1.18, 95% CI 0.88-1.60 for papers published before 2000 and meta-RR=1.20, 95% CI 1.06-1.36 for studies after 2000. These data do suggest an association between lymphatic and haematopoietic cancer and firefighting which reaches significance; however, this is based on one study published after 2000.

**Figure 15** Forest Plot of Lymphatic and Haematopoietic Cancers by Publication Year

### 3.2.17 Hodgkin’s Disease

Within the previous review, there was too little information on which to base summary risk estimates or to suggest an association between Hodgkin’s Disease and firefighting (Graveling and Crawford, 2010). There has been limited research published since then as Zeig-Owens et al., (2011) had too few cases to report on. One case-control study based on Californian firefighters identified an odds ratio of 1.22, 95% CI 1-1.5 (Tsai et al., 2015).

A meta-analysis was carried out to include data from the previous review from papers including Aronson et al., 1994, Demers et al., 1994, Kang et al., 2008b, Ma et al., 2006. When collated the meta-RR=1.18, 95% CI 0.98-1.43 (p=0.606 for heterogeneity). However, the studies included odds ratios and standardised mortality odds ratios which are prone to bias.
When examining the data for publication pre and post 2000, the meta-RR= 0.50, 95% CI 0.09-6.42 for the two studies published before 2000. For studies published post 2000, a meta-RR=1.18, 95% CI 0.98-1.43 was calculated. These data are presented in Figure 16. These data do not show a significant association.

![Hodgkin's disease](image)

**Figure 16** Forest Plot for Hodgkin’s Disease and Publications pre and post 2000

### 3.2.18 Non-Hodgkin’s Lymphoma (NHL)

Although the systematic review by Graveling and Crawford (2010) calculated an estimated risk relative to the general population ranging from 0.65-2.04. The review also reports that risk estimates were reducing during the period of papers reviewed (published between 1993 and 2008). In examining more recent research, risk estimates in cohort studies published since 2010 range between 0.98-1.81 (Daniels et al., 2013, Glass, 2009, Pukkala et al., 2014, Zeig-Owens et al., 2011) with only one study showing a statistically significant association with firefighting, SIR= SIR 1.81, 95% CI 1.12–2.76 (Ahn et al., 2012). The one case-control study included within this review identified a significant association for Californian firefighters of OR=1.22, 95% CI 1-1.5 for firefighters compared to individuals with four specified control cancers unlikely to be associated with firefighting (Tsai et al., 2015).

A meta-analysis was carried out to further evaluate risks of NHL. Data was collated from papers included in the previous review (Aronson et al., 1994, Baris et al., 2001, Bates, 2007, Beaumont et al., 1991, Demers et al., 1994, Giles et al., 1993, Kang et al., 2008b, Ma et al.,

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4 Minor discrepancies in numbers between the plot and the report are due to rounding
2006, Sama et al., 1990). The meta-RR calculated for a fixed effects model was meta-RR=1.14, 95% CI 1.05-1.23 (p=0.591 for heterogeneity). When examining the impact of publications pre and post 2000, a meta-RR=1.33, 95% CI 1.08-1.63 for studies published before 2000 and meta-RR=1.11, 95% CI 1.02-1.21 for those published after 2000. These data suggest a decrease in risk when compared to earlier studies but further in-depth analysis is required to evaluate this thoroughly. These data are presented in Figure 17.

![Non-Hodgkin's lymphoma](image)

**Figure 17** Forest Plot of NHL and Publication Dates pre and post 2000

### 3.2.19 Multiple Myeloma

In relation to multiple myeloma, an estimated risk relative to the general population was found to be between 1.4-1.5 (Graveling and Crawford 2010). Two cohort studies carried out since 2010, while finding a risks of between 0.76-1.13, did not reach significance (Daniels et al., 2013, Pukkala et al., 2014), while a further two cohort studies did not identify enough cases to analyse (Glass, 2009, Zeig-Owens et al., 2011). The case-control study of Californian firefighters did reach significance with an OR=1.35, 95% CI 1.00-1.82 (Tsai et al., 2015).

To examine these data further, a meta-analysis was carried out including the studies examined in the 2010 review (Aronson et al., 1994, Baris et al., 2001; Bates, 2007, Burnett et al., 1994, Demers et al., 1994, Kang et al., 2008b, Ma et al., 2006).

The fixed effects analysis yielded a meta-SMR=1.12, 95% CI 0.99-1.27 (p=0.202 for heterogeneity). When examining the publication year of the studies it was identified that the
studies included odds ratios from one case-control study and two mortality rate studies (prone to bias) and two mortality studies where it was unknown what type of ratio had been calculated, thus caution must be taken with the results. For studies published pre 2000, a meta-RR=1.12, 95% CI 0.99-1.27 was calculated versus a meta-RR=1.08, 95% CI 0.93-1.25 for studies post 2000. These data suggest that there is not a significant association between multiple myeloma and work as a firefighter. The data are presented in Figure 18.

![Forest Plot of Multiple Myeloma and Publications pre and post 2000](image)

**Figure 18** Forest Plot of Multiple Myeloma and Publications pre and post 2000

### 3.2.20 Leukaemia

Research examining leukaemia in firefighters in the 2010 systematic review gave an estimated risk relative to the general population of 1.1 (Graveling and Crawford, 2010). In examining papers since this review, risk estimates in cohort studies have ranged between 0.66-1.2 but none of the studies reach statistical significance (Ahn and Jeong, 2015, Daniels et al., 2013, Glass, 2009, Pukkala et al., 2014, Zeig-Owens et al., 2011). The one case-control study included in the review did identify a statistically significant association between leukaemia and firefighting in Californian firefighters (OR=1.32, 95% CI 1.05-1.66).

The majority of studies do not show an excessive risk of leukaemia in firefighters but a meta-analysis was carried out including the papers from the 2010 review Aronson et al., 1994, Baris et al., 2001, Bates et al., 2001, Beaumont et al., 1991, Burnett et al., 1994, Demers et al., 1994, Kang et al., 2008b, Ma et al., 2006, Sama et al., 1990. The meta-analysis for fixed effect identified a meta-RR=1.04, 95% CI 0.95-1.14 (p=0.217 for heterogeneity). However, the papers by Glass (2009) and Beaumont et al., (1991) collated results for leukaemia and
myelodysplastic diseases and aleukaemia and their exclusion from the analysis resulted in a meta-RR=1.05, 95% CI 0.96-1.14.

When examining publications published pre 2000, a meta-RR=1.14, 95% CI 0.95-1.14 and for post 2000, meta-RR=1.03, 95% CI 0.93-1.13. However, caution must be taken with these results while case-control studies give a better understanding of potential confounding factors, cohort studies give a better understanding of exposures. Figure 19 presents the Forest Plot of the analysis.

![Forest Plot of Leukaemia and Publications pre and post 2000](image)

**Figure 19** Forest Plot of Leukaemia and Publications pre and post 2000

### 3.2.21 The Meta-Analyses

Data were extracted from individual papers into the meta-analysis and the full results are presented in Table 2 below.
Table 2 Results of Meta-analyses

<table>
<thead>
<tr>
<th>Cancer</th>
<th>Fixed effect (FE) meta-RR</th>
<th>95% CI for FE meta-RR</th>
<th>P-value for heterogeneity</th>
<th>Random effects (RE) meta-RR</th>
<th>95% CI for RE meta-RR</th>
<th>p-value for difference between subgroups</th>
<th>P-value for publication bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>0.95</td>
<td>0.86 to 1.05</td>
<td><strong>0.003</strong></td>
<td>0.93</td>
<td>0.78 to 1.12</td>
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<td></td>
<td>1.09</td>
<td>0.75 to 1.61</td>
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<td>Stomach, 2000 or later</td>
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<td></td>
<td>0.85</td>
<td>0.72 to 1.02</td>
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<td></td>
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<tr>
<td>Oesophagus</td>
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<td>1.12 to 1.40</td>
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<td>1.09</td>
<td>0.84 to 1.43</td>
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<td></td>
<td>1.03</td>
<td>0.76 to 1.40</td>
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</tr>
<tr>
<td>Colon &amp; rectum</td>
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<td>1.08 to 1.20</td>
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<tr>
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<td>1.05 to 1.29</td>
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<td>0.89 to 1.13</td>
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<td>Cancer</td>
<td>Fixed effect (FE) meta-RR</td>
<td>95% CI for FE meta-RR</td>
<td>P-value for heterogeneity</td>
<td>Random effects (RE) meta-RR</td>
<td>95% CI for RE meta-RR</td>
<td>p-value for difference between subgroups</td>
<td>P-value for publication bias</td>
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<td>P-value for heterogeneity</td>
<td>Random effects (RE) meta-RR</td>
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<td>p-value for difference between subgroups</td>
<td>P-value for publication bias</td>
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<td>Cancer</td>
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<td>P-value for heterogeneity</td>
<td>Random effects (RE) meta-RR</td>
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<td>p-value for difference between subgroups</td>
<td>P-value for publication bias</td>
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<td>Leukaemia</td>
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3.3 RESEARCH PAPERS EXAMINING EXPOSURE AND CANCER INCIDENCE

One of the major issues when examining firefighters and possible exposures to potential carcinogens are the variety of potential exposures that such individuals are exposed to. Fritishi and Glass (2016) in their commentary on firefighters and cancer identified that exposures are different if the fire is in a rural or urban environment or whether the firefighters are dealing with combustion, chemical spills or substances unknown.

Attempts have been made to measure exposures using techniques such as number of call outs, years of work and person-hours. As an example, Daniels et al., (2014) examined exposure days, number of fire runs and fire hours. The analysis identified that there were significant associations measured in hazard ratios between the incidence of lung cancer and fire hours (HR=1.39, 95% CI 1.10-1.74) based on 2300 fire hours with a referent of 600 hours, and mortality from leukaemia and the number of fire runs attended (HR=1.45, 95% CI 1.00-2.35) based on 8800 runs with a referent of 2100 runs.

It is important to note here that this is one cohort study, involving US firefighters. Whereas lung cancer rates are not identified as significantly raised internationally, this may be a reflection of different exposures through different methods of working between countries. This will be a focus of future work.

3.4 RESEARCH PAPERS EXAMINING OTHER COMPARABLE GROUPS AND CANCER INCIDENCE

Other groups of emergency response services were included in the literature search to consider how comparable any increases in risk of cancer between services are. Three papers were identified which studied cancer incidence in police officers.

Finkelstein (1998) analysed cancer incidence data for a cohort of 22,197 police officers in Ontario between 1964 and 1995. The author highlighted that for most cancer sites the SIRs were lower than expected, particularly low for lung cancer, and overall lower than the general population. Incidence rates for three cancer sites in Finkelstein’s study included; prostate cancer (SIR 1.16, 95% CI: 0.93-1.43) testicular cancer (SIR 1.30, 90%CI: 0.89-1.84) and melanoma skin cancer (SIR 1.45, 90% CI: 1.10-1.88), only the melanoma rate was significantly raised.

Feuer and Rosenman (1986) completed a study on mortality in firefighters and police in New Jersey. They carried out a proportionate mortality ratio (PMR) study of 567 police officers who died between 1974 and 1980. They found no significant elevations in cancer rates for the large intestine (PMR=1.83) and skin cancer (PMR=2.10). For firefighters, significant elevations in skin cancer were found (PMR=1.48). Both studies used the American population as a comparator. Similarly, Kang et al (2008) also included in their study on firefighters in Massachusetts a cohort of police officers as a comparison group. However, in their study they found a moderate elevation for colon cancer (SMOR = 1.36, 95% CI: 1.04-1.79) and brain cancer (SMOR = 1.90, 95% CI: 1.10-3.26) in the police comparison group, a cohort of 2,763 police officers. Furthermore, no evidence of increased risk was found in bladder cancer (SMOR = 1.22, 95% CI: 0.89-1.69), kidney cancer (SMOR 1.34, 95% CI: 0.90-2.01), and Hodgkin’s lymphoma (SMOR = 1.81, 95% CI: 0.72-4.53).
4 DISCUSSION

4.1 DATA USED WITHIN THE REPORT

The data used for the meta-analyses was collated from the published research. As such there are often sources of bias within the data. For example, cohort studies often have uncontrolled confounding and possible selection biases; case-control studies may suffer from recall bias if exposure assessment is subject to participants’ recollections.

In addition to this, there is also the risk of different diagnostic criteria being used within the paper set as well as the collation of different cancers. For example, colon cancer and rectal cancer are often collated together which may have an impact on the analysis. This report separated the data on both cancers. Furthermore, the use of the term ‘skin cancer’ includes cancer with different established aetiologies so caution must be taken when analysing and interpreting these data.

The method of data extraction evaluated each of the papers individually but most of the findings were based on 4 cohort studies and one case-control study. While the ICD codes were used in most of the papers, the lack of breakdown of cancer types such as skin cancer into melanoma and non-melanoma and, colorectal into colon and rectal cancers does not allow clarity within the data-sets. The data also represent an international perspective and it should be borne in mind that there are different work practices, different levels of protection and different work processes between national borders. For example, in the USA, firefighters often work as paramedics too. At the current time the information is not readily available to evaluate work processes for each individual country.

The analyses presented use comparisons with the general population. It was proposed to use other groups such as police officers or paramedics as a comparator. The research identified during the searches was not of a good enough quality to allow an accurate comparison. It was highlighted that for police officers in particular, data on health outcomes are poor at the current time.

4.2 CANCERS IDENTIFIED AS HAVING A RAISED RISK

From the meta-analyses, a number of cancers were identified as having a raised risk among firefighters including colon, rectal, skin cancer, prostate cancer, bladder cancer, kidney cancer, lymphatic and haematopoietic cancer and Non-Hodgkin’s Lymphoma. One cancer which had previously found to be significantly associated with firefighting by others was testicular cancer but in this this was not found to be significant in this analysis.

For colon and rectal cancer an issue highlighted earlier was that of the collation of the results into colorectal cancer. In the meta-analyses, the separate calculations for colon and rectal cancer were both found to be significant. Further analysis of the potential risk factors for both these cancers should be examined.

The analysis of skin cancer and firefighters’ studies also highlighted some of the issues in relation to the diagnostic criteria used. In the separate analysis carried out, melanoma was found to have a significant association but non-melanoma skin cancer did not. This allows future focus on melanoma to examine other potential risk factors in future work.
For the final four cancers, where a significant association was identified (prostate, bladder, kidney and lymphatic and haematopoietic cancers) a further examination of potential risk factors for these cancers should also be examined in the next stage of work.

The absence of a significant association with testicular cancer identified in this work compared to previous studies may be as a result of increased awareness among the firefighting population with regard to screening and self-care which has only become evident in the more recent papers.

4.3 EVIDENCE GAPS

There are still a number of evidence gaps within the existing body of research including a lack of research papers including female firefighters and the use of consistent coding of cancers within internationally agreed methods. Furthermore, the research is hindered by a lack of consistent exposure assessment with regard to the number and length of fire incidents individuals attend during their working life.

While there is an increasing data available for comparison and analysis among firefighters, this also needs to be supported by additional data in relation to exposure-response, whether that is to use methods such as fire hours, number of callouts or time in employment. Furthermore, the need to allow a sufficient follow-up period for those involved in firefighting as an occupation.
5 CONCLUSIONS

The research presented here has identified a number of significant excesses of cancer among firefighters, none of which reach a high level such as a doubling of risk. It is recommended that further research examining the risk factors for colon, rectal, prostate, bladder, kidney and lymphatic and haematopoietic cancers be further examined in the next stage of work.
ACKNOWLEDGEMENTS

The authors would like to thank the following organisations for funding this research. Kingspan, EUMEPS, EUPC, Plastics Europe, EXIBA, PU Europe.
REFERENCES


Stata Statistical Software: Release 13. College Station, TX. StataCorp LP.


APPENDIX 1. SEARCH PROTOCOL

QUESTIONS TO BE ADDRESSED BY THE RESEARCH

This search protocol was developed in response to the three research questions below. This document only reports on the systematic review and meta-analyses for question 1. In total, 8 of the papers identified within the searches, excluded from question 1 will be included for question 2.

The research question to be addressed by this review are the following:

1. What is the epidemiological evidence of the incidence of specific cancers in firefighters, and how does this compare to other comparable occupational groups.
2. What is known about the occupational risk factors for those cancers where a higher risk is identified?
3. What occupational hazards are firefighters exposed to?

SEARCH STRATEGY FIRE-FIGHTERS AND CANCER

Q1 What is the epidemiological evidence of the incidence of specific cancers in firefighters, and how does this compare to other comparable occupational groups?

Population
- Fire-fighters
- Firefighter
- Fire Fighter
- Firemen
- Fire Personnel
- Smoke Jumper
- Emergency service
- Emergency service personnel
- Fire Service

Outcomes
- Disease
- Illness
- Ill-health
- Occupational disease
- Occupational health
- Cancer(s)

Study Designs
- Systematic reviews
- RCTs
- Case control studies
- Cohort and nested case-control studies
- Cross-sectional studies
- Observational studies
- Narrative Reviews

Inclusion Criteria for Review
- Studies containing usable data
In English
Post 2009

**Exclusion Criteria for Review**
Studies containing no data
Non-English language

**Search Tools**

**Databases**
Medline
PsychInfo
Science Citation Indexes

**Websites**
NIOSH
European Agency for Safety and Health
HSE
CCSRI
Canadian Cancer Society
National Institutes for Health

**Organisations**
Home Office Fire Research Group
FBU
International Firefighter Organization
International Association of Fire Fighters (IAFF)

**Search String**
epidemiology AND (incidence OR mortality) AND cancer AND (Fire-fighter OR Firefighter OR "Fire Fighter" OR Firemen OR "Fire Personnel" OR "Smoke Jumper" OR "Emergency service" OR "Emergency service personnel" OR "Fire Service" OR “police officers” OR paramedics )

**Q2 What is known about the occupational risk factors for those cancers where a higher risk is identified?** (not reported in this document)

**Cancers**
Cancers included in this question will be those that are identified in question where epidemiological judgement suggests there is an increased risk.

**Risk factors**
Occupational exposure
Life style (smoking, diet, activity, etc)
Genetic factors
Socio-economic factors

**Search String**
cancer AND “risk factors”
Q3 What occupational hazards are firefighters exposed to?
(not reported in this document)

**Population**
Fire-fighters
Firefighter
Fire Fighter
Firemen
Fire Personnel
Smoke Jumper
Emergency service
Emergency service personnel
Fire Service

**Hazards**
Occupational exposure

**Search String**
(fire-fighter OR Firefighter OR "Fire Fighter" OR Firemen OR "Fire Personnel" OR "Smoke Jumper" OR "Emergency service OR "Fire Service") AND (hazards OR risks) AND (exposure OR epidemiology)
## APPENDIX 2. PAPERS EXCLUDED DURING DATA EXTRACTION

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<thead>
<tr>
<th>Authors</th>
<th>Reason for Exclusion</th>
</tr>
</thead>
<tbody>
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<td>Aschebrook-Kilfoy et al., (2014)</td>
<td>Does not include firefighters in the sample</td>
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<tr>
<td>Beranger et al., (2013)</td>
<td>Does not include firefighters in the sample and considers cancer in offspring.</td>
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<td>Amadeo et al., (2015)</td>
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<td>Walsh et al., (2014)</td>
<td>Cancer screening not occurrence</td>
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<tr>
<td>Yip et al., (2016)</td>
<td>Does not include cancer outcomes</td>
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<td>Centers for Disease Control and Prevention (2012)</td>
<td>Final ruling on cancer and compensation</td>
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<td>Poston et al., (2012)</td>
<td>Tobacco use among firefighters</td>
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<td>Wong &amp; Gomes (2016)</td>
<td>Duplicate</td>
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<td>Wirth (2013)</td>
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# APPENDIX 3. STUDIES INCLUDED IN THE REVIEW

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<th>Population</th>
<th>Findings</th>
<th>Quality Assessment</th>
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<td>Ahn &amp; Jeong (2015)</td>
<td>Cohort Study</td>
<td>Firefighters and Emergency Responders</td>
<td>The cohort was comprised of all male professional emergency responders employed for at least one months between January 1980 and December 2007. In total 33,442 workers were followed for 377,703 person-years. Firefighters made up 81% of the cohort (29,453 workers). For firefighters SMR for cancer was calculated for stomach cancer (0.63, 95% CI 0.43-0.88), colorectal cancer (0.55, 95% CI 0.34-1.14) for liver cancer (0.55, 95% CI 0.41-0.84) lung cancer (0.58, 95% CI 0.38-0.84) leukaemia (0.66, 95% CI 0.24-1.44) Lymphohematopoietic (0.91, 95% CI 0.51-1.50). Within the emergency responders group (all of the cohort), cancers examined included stomach (0.61, 95% CI 0.43-0.67), colorectal (0.66, 95% CI 0.35-1.14), liver (0.52, 95% CI 0.39-0.69), lung (0.59, 95% CI 0.39-0.85), leukaemia (0.61 95% CI 0.22-1.32), lymphohematopoietic (0.89, 95% CI 0.51-1.45). Mortality due to exposure to smoke, fire, and flames (SMR=3.11, 95% CI=1.87–4.85) was significantly increased among ERs All-cause mortality (ARR=1.46, 95% CI=1.13–1.89), overall cancer mortality (ARR=1.54, 95% CI=1.02–2.31) and mortality of external in-jury, poisoning and external causes (ARR=3.13, 95% CI=1.80–5.46) were significantly increased among firefighters employed 20 years compared to those of non-firefighters and firefighters employed &lt; 10 years.</td>
<td>+</td>
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</table>

| Ahn, et al (2012)       | Cohort Study    | Korean Firefighters           | The total cohort was 33146 male emergency responders and within the cohort, 29438 were firefighters. Data were collected between 1980 and 2007. Standard incidence ratios identified that risks for colorectal cancer (SIR=1.27, 95% CI 1.01-1.59), kidney cancer (SIR=1.56, 95% CI 1.01-2.41), bladder cancer (SIR=1.6, 95% CI 1.01-2.56) and non Hodgkins lymphoma (SIR=1.69, 95% CI 1.01-2.67) were significantly higher than the male Korean population. When examining duration of employment, bladder cancer was at an increased incidence at employment of 10 years and longer (SIR=1.98, 95% CI 1.13-3.22). | ++                 |

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Research Report TM/17/01
<table>
<thead>
<tr>
<th>Author</th>
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<th>Population</th>
<th>Findings</th>
<th>Quality Assessment</th>
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<td>Review</td>
<td>Firefighters</td>
<td>This was a review of epidemiological studies for associations between firefighters and selected cancers. The report was carried out to examine the strength of association between firefighters and specific cancers with a view to considering a presumption of the cancers for compensation. The review identified that for multiple myeloma, all studies were limited by small numbers. However, the majority did identify increased rates including an increase after 20 years’ service. For stomach cancer, inconsistent results were found with again the limitation of small numbers. An association was identified with over 30 years of employment (SIR=2.56, 95% CI 1.49-5.05) and attending over 1000 fires (SIR=2.64, 95% CI 1.36-4.61). The review of prostate cancer the 15 included studies were again inconsistent. One study did identify increased mortality for those working less than 9 years (SMR=2.36, 95% CI 1.42-3.91) and with over 30 years employment (SMR=1.42, 95% CI 1-2). The review included 4 papers examining testicular cancer were again limitations with regard to numbers were highlighted. The studies did identify an increased incidence between 11-20 years employment (SIR=3.51, 95% CI 1-9). For rectal cancer, 13 studies were included but only one significant association was identified which was age of occurrence being over 65 years old (PMR =1.86, 95% CI 1.1-2.94). Digestive tract cancer risks were evaluated using 9 studies but again results were inconclusive and did not show a positive association apart from occurring at over 65 years of age (SIR=3.65, 95% CI 1.13-7.94). Conflicting evidence of any meaningful association between prostate cancer and the firefighting occupation is derived from the studies described above.</td>
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<td>Daniels et al (2013)</td>
<td>Cohort Study</td>
<td>Firefighters</td>
<td>The study examined mortality patterns and incidence among a group of 29,993 firefighters which measured mortality rates of specific cancers, standard incident rates and made a comparison with the US general population. Analyses focused on 15 outcomes of a priori interest. Sensitivity analyses were conducted to examine the potential for significant bias. Person-years at risk totalled 858,938 and 403,152 for mortality and incidence analyses, respectively. All-cause mortality was at expectation (SMR=0.99, 95% CI 0.97 to 1.01, n=12,028). There was excess cancer mortality (SMR=1.14, 95% CI 1.10 to 1.18, n=3,285) and incidence (SIR=1.09, 95% CI 1.06 to 1.12, n=4,461) comprised mainly of digestive (SMR=1.26, 95% CI 1.18 to 1.34, n=928; SIR=1.17, 95% CI 1.10 to 1.25, n=930) and respiratory (SMR=1.10, 95% CI 1.04 to 1.17, n=1,096; SIR=1.16, 95% CI 1.08 to 1.24, n=813) cancers. This study is the first to report excess malignant mesothelioma (SMR=2.00, 95% CI 1.03 to 3.49, n=12; SIR=2.29, 95% CI 1.60 to 3.19, n=35) among US firefighters. Mortality for women did not show an excess and most cancer deaths were from breast cancer and bladder cancer but this was based on a few cases. Over time, oesophageal cancer rates were shown to be increased between 10-20 years’ service and 20-30 years but not after 30 years. Stomach cancer incidence was increased after 30 years of service. Intestinal cancer rates were increased between 20-30 years of service; lung cancer rates reached a peak at 2030 years of service; as did kidney cancer rates. Non-Hodgkin’s lymphoma had a higher than expected incidence between 20-30 years’ service and after 30 years of service.</td>
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<tr>
<td>Daniels et al (2015)</td>
<td>Cohort Study</td>
<td>Firefighters</td>
<td>This research paper examined a cohort of 19309 male firefighters who were eligible for the study where there had been 1333 cancer deaths and 2609 cancer incidences. The aim was to examine exposure–response relationships between surrogates of firefighting exposure and select outcomes among previously studied US career firefighters. Eight cancer and four non-cancer outcomes were examined using conditional logistic regression. Incidence density sampling was used to match each case to 200 controls on attained age. Days accrued in firefighting assignments (exposed-days), run totals (fire runs) and run times (fire-hours) were used as exposure surrogates. Significant positive associations between fire-hours and lung cancer mortality and incidence were evident. A similar relation between leukaemia mortality and fire-runs was also found. The lung cancer associations were nearly linear in cumulative exposure, while the association with leukaemia mortality was attenuated at higher exposure levels and greater for recent exposures. Significant negative associations were evident for the exposure surrogates and colorectal and prostate cancers, suggesting a healthy worker survivor effect possibly enhanced by medical screening. Lung cancer and leukaemia mortality risks were modestly increasing with firefighter exposures. There was a significant association between fire runs and leukaemia mortality (1.45, 95% CI 1.00-2.35) and lung cancer mortality and fire-hours (1.39, 95% CI 1.12-1.73). For cancer incidence, significant associations were found for lung cancer (1.39, 95% CI 1.1-1.74).</td>
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<td>Davis et al (2012)</td>
<td>Cohort Study</td>
<td>Criminal Investigators, US with BATFE</td>
<td>This was a cohort study of 3,768 individuals predominately made up of criminal investigators, the majority of whom were male. The study examined the incidence of bladder cancer but did include both self-report and clinically diagnosed outcomes. Person-years were also calculated and seven cases of bladder cancer, five medically documented, occurred during the period of study. Standardised incident rates were calculated and found to be significant for all cases (SIR=2.41, 95% CI 1.17-4.96) but not significant where only the 5 medical cases were included. For the breakdown of the cohort into white males, white males taking exams and those with the Job 1811 as their title, significant incidence was found with those taking exams (SIR=4.34, 95% CI 1.85-10.16), those with Job 1811 (SIR=5, 95% CI 2.33-12.76) and medically diagnosed cancer. The paper suggests that some officers are exposed to post-fire and post-blast scenes where there is the potential to be exposed to risks for bladder cancer.</td>
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<tr>
<td>Driscoll et al (2016)</td>
<td>Cohort Study</td>
<td>Firefighters</td>
<td>The aim of the study was to produce a population based estimate of formaldehyde exposure. The main exposure routes for firefighters were through exposure to particle board during firefighting and overhaul.</td>
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<td>Fang et al (2011)</td>
<td>Case-control Study</td>
<td>General Population and firefighters</td>
<td>This was a Canadian population based case-control study which aimed to examine elevated colon cancer risks in occupation. The analysis included 15463 incident cases and a number of organisations. Firefighters were not found to have an elevated risk of colon cancer within this study.</td>
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<tr>
<td>Fritschi &amp; Glass (2016)</td>
<td>Consensus or Expert Opinion</td>
<td>Firefighters</td>
<td>This was a commentary with regard to firefighters and cancer and where we are now. The article highlights the different incidence rates in different cohorts and that firefighting includes a range of diverse activities. Exposures may be different due to the types of fires, the sites of fires (urban or rural), chemical spills, MVAs and the materials used in buildings have changes. Firefighters should be encouraged to reduce exposure by PPE and RPE as well as protecting the skin.</td>
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<td>Glass, (2009)</td>
<td>Cohort Study</td>
<td>Australian Firefighters</td>
<td>This was a retrospective cohort study of firefighters. The analysis identified 208 cancers among the 6964 men and 9 among the 540 women. There were no excess incidences established for any of the cancers examined by the research for men. For women, there were too few cases to report. In addition, similar patterns of cancer incidence were found when restricting the analysis to those male fire fighters with more than 1 years’ service or when restricting the analysis to fulltime fire fighters</td>
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<td>Graveling &amp; Crawford (2010)</td>
<td>Systematic Review</td>
<td>Firefighters and cancer</td>
<td>This was a systematic review published for the UK Industrial Injuries Advisory Council (IIAC) to examine possible prescription of different health risks including cancer in firefighters as an industrial injury. The review examined cancers and identified that while none of the cancers examined reached a doubling of risk (the threshold for prescription in the UK), there was an observed increased risk for (above 1) for mouth cancers, oesophageal, colon cancer, rectal cancer, skin cancer, prostate cancer, testicular cancer, bladder cancer, kidney cancer, brain cancer, brain cancer, lymphatic and haemopoietic cancers, non-Hodgkin’s Lymphoma, multiple myeloma and leukaemia.</td>
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<td>Gomes et al (2011)</td>
<td>Review</td>
<td>General Population and firefighters</td>
<td>This was a review examining brain neoplasms. The study identified that firefighters had a moderately higher risk for brain neoplasms compared to other workers. The review cites other relevant studies but does not synthesise the knowledge.</td>
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<td>Gu, et al (2011)</td>
<td>Cohort Study</td>
<td>Police Officers</td>
<td>This is a cohort study of US police officers. In total 2234 white male police officers were included in the study with a follow-up of 31 years. The analysis identified that 406 officers developed cancer and the overall cancer incidence was similar to the general population. The risk of overall cancer among police officers was found to be similar to the general white-male population (Standardized Incidence Ratio [SIR] = 0.94, 95% CI = 0.85–1.03). An elevated risk of Hodgkin’s lymphoma was observed relative to the general population (SIR = 3.34, 95% CI = 1.22–7.26). The risk of brain cancer, although only slightly elevated relative to the general population (SIR = 1.61, 95% CI = 0.73–3.05), was significantly increased with 30 years or more of service (SIR = 2.92, 95% CI = 1.07–6.36). Incidence ratios were significantly lower than expected for skin and bladder cancer. Police officers were at increased risk of Hodgkin’s lymphoma overall and of brain cancer after 30 years of service. However, an elevated risk of non-Hodgkin’s lymphoma was observed (SIR = 3.34, 95% CI 1.22–7.26). Incidence rates were significantly lower for skin and bladder cancer.</td>
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<td>Guidotti, (2007)</td>
<td>Review</td>
<td>Firefighters</td>
<td>The paper discusses causality in cancers associated with firefighting and compensation in Canada. The paper suggests that presumption is justified for bladder, kidney, testicular, brain and lung cancer among non-smokers. There were difficulties in making presumption for non-Hodgkin lymphoma, leukaemia and myeloma.</td>
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<td>Ide, C. W.</td>
<td>Cohort Study</td>
<td>Firefighters with a general population comparator group</td>
<td>The study aimed to examine cancer morbidity and mortality among Scottish firefighters. The sample ranged between 2173-2308 between the periods of 1984 and 2005. Overall mean annual cancer incidence and mortality rates were lower in the firefighters (86.5 versus 123.7, ( P &lt; 0.01 ), 95% [CI] –290.3 to –209.7 and 20.4 versus 59.9, ( P &lt; 0.001 ), 95% CI –57.5 to –22.5, respectively). The incidences of melanoma and kidney cancers were higher (13.6 versus 7.7, ( P &lt; 0.001 ) 95% CI 3.0 to 8.8 and 9.1 versus 4.4, ( P &lt; 0.01 ), 95% CI 2.4 to 6.7) as was mortality from kidney cancer (6.5 versus 1.9, ( P &lt; 0.001 ), 95% CI 2.8 to 6.4). Large bowel (( P &lt; 0.01 ), 95% CI –7.7 to –1.7) and lung (( P &lt; 0.001 ), 95% CI –7.7 to 1.0) had a significantly lower than expected incidence. Mean age and length of service at diagnosis were 43 years (range 28–54) and 19 years (range 2–31), respectively. These results are generally consistent with other studies of firefighters. The most common tumours were generally those associated with young and middle-aged men.</td>
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<tr>
<td>Paget-Bailly, et al (2013)</td>
<td>Case-control Study</td>
<td>Firefighters</td>
<td>This paper is from a French population based research project (ICARE) which examined occupation and head and neck cancer. The analysis included 2415 cases and 3555 controls. Within the population, there were 13 firefighters and 12 controls. For those ever employed as a firefighter, the risk of head or neck cancer was 3.9 (95% CI 1.4-11.2) and for with more than 10 years as a firefighter this was calculated at 7.6 (95% CI 2.4-24) but was not elevated for those with less than 10 years in the occupation.</td>
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Pukkula et al (2014)

**Type of Study:** Cohort Study

**Population:** Firefighters

This is a cohort study of 16,422 firefighters from Sweden, Finland, Norway, Denmark and Iceland followed up between 1961 and 2005. For all cancers the SIR calculated was 1.06 95% CI 1.02-1.11. For specific cancers the SIR was for adenocarcinoma (1.24 95% CI 1.02-1.6) for skin melanoma (1.25, 95% CI 1.03-1.51), prostate cancer (1.13, 95% CI 1.05-1.22). The study also examined cancer incidence in different age groups, 30-49 years, 50-69 years and 70+ years. These data identified an increase in incidence with age apart from for prostate cancer which decreased with age. Some of these associations have been observed previously, and potential exposure to polycyclic aromatic hydrocarbons, asbestos and shift work involving disruption of circadian rhythms may partly explain these results. By contrast, an increased risk, mainly in ages of 70 years and higher, was observed for non-melanoma skin cancer (SIR=1.40, 95% CI 1.10 to 1.76), multiple myeloma (SIR=1.69, 95% CI 1.08 to 2.51), adenocarcinoma of the lung (SIR=1.90, 95% CI 1.34 to 2.62), and mesothelioma (SIR=2.59, 95% CI 1.24 to 4.77). In comparison to earlier studies, the incidence of testicular cancer was decreased (SIR=0.51, 95% CI 0.23 to 0.98).

Quality Assessment: ++

Samet & Bhavsar (2005)

**Type of Study:** Review

**Population:** Firefighters

This is a report that covers a number of different aspects cancer in firefighters in Maryland. This report provides the findings of a ten-month study of a possible cancer cluster among fire fighters in Anne Arundel County. Firefighters are exposed to smoke generated by the combustion of diverse materials, and the smoke is known to contain carcinogens. This report covers a range of topics and activities relevant to interpreting the possible cancer cluster. These activities included characterizing the cluster and evaluating potential exposures to PCBs and their combustion by-products of fire fighters who participated in training fires at the Academy, assessment of applicable scientific literature, and consideration of research that might provide greater insight into the risks sustained by fire fighters. The authors suggest that the risk of death from brain cancer was increased by 30 percent in firefighters but no formal comparison was carried out. Although the paper does review a number of studies, it does not synthesise the data in any way.

Quality Assessment: -
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<td>Tsai, et al (2015)</td>
<td>Case-control</td>
<td>Firefighters</td>
<td>The study identified a cohort of 3996 male firefighters using California Cancer Registry data. Controls were individuals with four specified control cancers unlikely to be associated with firefighting. Elevated risks were found for melanoma (OR=1.8, 95% CI 1.4-2.1), multiple myeloma (OR=1.4, 95% CI 1-1.8), acute myeloid leukaemia (OR=1.4, 95% CI 1-2), oesophageal cancer (OR=1.6, 95% CI 1.2-2.1), prostate cancer (OR=1.5, 95% CI 1.3-1.7), brain (OR=1.5, 95% CI 1.2-2) and kidney cancer (OR=1.3, 95% CI 1-1.6). Further analysis examined various cancers among other race and ethnic groups. The risk of lip cancer was elevated (OR=4.57, 95% CI 1.23-10.35), melanoma (OR=4.51, 95% CI 1.85-10.97), prostate cancer (OR=2.42, 95% CI 1.53-3.84), testicular cancer (OR=3.73, 95% CI 1.26-11.02), bladder cancer (OR=2.37, 95% CI 1.05-5.33), kidney cancer (OR=2.69, 95% CI 1.4-4.8), brain cancer (OR=3.58, 95% CI 1.65-7.74), non-Hodgkin’s Lymphoma (OR=2.17, 95% CI 1.2-3.92), multiple myeloma (OR=3.77, 95% CI 1.91-7.44), leukaemia (OR=3.64, 95% CI 1.96-6.74) and leukaemia (OR=7.04, 95% CI 2.99-16.56). Some suggested mechanisms were also made in the paper including prostate cancer (increased screening), melanoma, sun exposure and exposure to PAH, PCBs, aromatic hydrocarbon and heavy oil and oesophageal cancer due to fire suppression and overhaul).</td>
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<td>Wirth, et al (2013)</td>
<td>Review</td>
<td>Police Officers</td>
<td>This was a review where the relevant databases were searched systematically but there was no attempt made to synthesise the data mainly due to the quality of studies identified. The paper did identify in police officers significant increases in mortality due to all cancer, digestive organ malignancies and oesophageal, colon, kidney, bladder, brain, lymphatic, haematopoietic tissue, endocrine gland, breast, testicular, melanoma and Hodgkin's disease. There appeared to be a dose response linked to number of years within the different research papers reviewed.</td>
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<td>Wong &amp; Gomes (2010)</td>
<td>Review</td>
<td>Firefighters</td>
<td>There has been some research on firefighter prostate cancer levels but few reviews on the topic. This paper focuses on finding whether there is a correlation between firefighting occupation and levels of prostate cancer. As well, this paper notes potential carcinogens within the firefighting occupation. Five papers were included in this review; these papers used different methods to obtain the cases and controls for the study. The papers also used different controls for comparison. The included papers found in the search supported a positive correlation between exposures in firefighting occupations and the level of prostate cancer. The two chemicals that were suspected carcinogens in these studies were Poly-aromatic hydrocarbons (PAH) and fire smoke.</td>
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<tr>
<td>Yip, et al (2015)</td>
<td>Cohort Study</td>
<td>Firefighters</td>
<td>The aim of the paper was to describe the health burden among Fire Department of the City of New York (FDNY) emergency medical service (EMS) workers and examine its association with work at the World Trade Center (WTC) disaster site. In this observational cohort study, we used FDNY physician diagnoses to estimate the cumulative incidence of physical health conditions including rhino sinusitis, gastroesophageal reflux disease (GERD), obstructive airways disease (OAD) and cancer among EMS workers and demographically similar firefighters who were active on 11 September 2001 (9/11). Among 2281 EMS workers, the 12-year post 9/11, the cumulative incidence of cancer 3.1%.</td>
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<td>Zeig-Owens et al (2011)</td>
<td>Cohort Study</td>
<td>WTC Firefighters</td>
<td>This paper examined cancer incidence and potential exposures in the seven years after 9/11 including health data collected before this date in a cohort of 9853 male firefighters. Cancer cases were confirmed with cancer registries or other appropriate documentation. The analysis identified that for WTC exposed firefighters, the SIR was 1.1, 95% CI 0.98-1.25. When compared to non-exposed firefighters, the SIR was 1.19, 95% CI 0.96-1.47 (corrected for surveillance bias).</td>
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- Environment
- Expert Witness Services
- Asbestos in Soils Services
- Lab Services
- Human Factors
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