



WORKING FOR A HEALTHY FUTURE

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Occupational health risks in firefighters

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EXECUTIVE SUMMARY

The Industrial Injuries Advisory Council (IIAC) invited the Institute of Occupational Medicine (IOM) to undertake a systematic review of the evidence relating to occupational health risks in fire-fighters, to assist the Council in advising the government on the prescription of industrial diseases. The primary research question to be addressed was:

Are published epidemiological data indicative of a significantly increased risk of disease in those employed as a fire-fighter, and, if so, is this risk more than doubled compared to that in the general population?

A search strategy was developed and agreed with the sponsor. Based on this, a number of electronic databases were searched, yielding a total of 678 references for potential inclusion. On retrieval of titles and abstracts an initial screening process was carried out by the research team working to specified guidelines. Where the relevance of the paper was not apparent from the title or, where available, the abstract, a conservative approach was taken and full publications were ordered to allow full text scanning.

On completion of the screening process, potential publications were obtained for review and data extraction. Papers were scanned further at initial acquisition to ensure they fitted the inclusion criteria. Those that were included were reviewed and data extracted. Additional material, in the form of papers cited by those selected for review, was also obtained where relevant and added to the review. Extracted data were then collated into evidence tables to support the narrative review.

Following drafting of the review a copy was made available to the reviewers of an unpublished review by the Canadian Industrial Disease Standards Panel (IDSP, 1994) on cardiovascular disease and cancer among firefighters. A note on this review has been added as Appendix D.

Cancers

A total of 34 papers, including some review papers, which made reference to some association (positive or negative) between cancer of various types and the occupation of fire fighting were selected to provide material for consideration as part of the review. The evidence given focuses mainly on those papers for which a Risk Estimate was presented, together with confidence intervals around that estimate.

The key findings from each of the cancers addressed can be summarised as follows:

Lip, oral (buccal) cavity and pharynx Eight papers provided usable Risk Estimates for cancers of the lip, oral cavity or pharynx, none of which were statistically significant. Some of these presented the findings for these cancers collectively, whilst others reported separate estimates for more specific diagnoses. From the papers which reported figures, it can be estimated that in excess of 553,161 person-years of follow-up contributed to this evidence. Individual risk estimates ranged from 0.66 (buccal cancer alone) to 1.43. After taking the relative sizes of each of these studies into account, it would appear that a collective Risk Estimate of 1.0-1.1 would seem reasonable, scarcely distinguishable from 1.0.

Oesophageal cancer Twelve papers presented usable Risk Estimates for oesophageal cancer. From the papers which reported figures, it can be estimated that in excess of 1,483,206 person-years of follow-up contributed to this evidence. Individual Risk Estimates ranged from 0.4 to 2.04, the latter being one of two papers reporting a significant positive association. One other paper presented a significant negative association. Taking the relative sizes of all of the studies into account an estimated Risk Ratio of 1.1-1.2 would seem appropriate, although unlikely to attain statistical significance.

Stomach cancer Seventeen papers presented usable Risk Estimates for stomach cancer. From the papers which reported figures, it can be estimated that in excess of 1,726,255 person-years of follow-up contributed to this evidence. Individual Risk Estimates ranged from 0.42 to 2.02, the former being one of two papers reporting a significant negative association. No papers reported a significant positive association. After allowing for the relative sizes of the different studies it would seem likely that a summary Risk Estimate close to 1.0 would seem appropriate suggesting that there is little or no substantive association between stomach cancer and being a firefighter.

Colon cancer There were thirteen papers which provided useable Risk Estimates of cancer of the colon. From the papers which reported figures, it can be estimated that in excess of 1,508,428 person-years of follow-up contributed to this evidence. Individual Risk Estimates ranged from 0.60 to 1.83, the latter being one of two which reported a significant positive association (none of the negative associations were statistically significant). Taking the relative study sizes into account lead to the conclusion that, although there is a lack of general consistency of findings between different studies, the collective evidence suggested a modest positive association between colon cancer and being a firefighter and that an estimate of around 1.2 would appear to give a reasonable guide.

Rectal cancer Fourteen papers provided useable Risk Estimates for rectal cancer. From the papers which reported figures, it can be estimated that in excess of 1,508,428 person-years of follow-up contributed to this evidence. Individual Risk Estimates ranged from 0.88 to 2.08. Only one estimate (positive association) attained statistical significance. It appeared that, as with colon cancer, there would appear to be a reasonably consistent positive association between rectal cancer and being a firefighter, such an association is undoubtedly modest (<1.3) and clearly below 2.0.

Pancreatic cancer There were sixteen papers which reported a useable Risk Estimate for cancer of the pancreas. From the papers which reported figures, it can be estimated that in excess of 1,529,281 person-years of follow-up contributed to this evidence. Risk estimates ranged from 0.38 to 1.55 and two of the reported estimates were statistically significant, one reporting an excess, the other a reduction in risk. These findings reinforce the suggestion from the current review of no meaningful difference between firefighters and the general population in the risk of developing pancreatic cancer (Risk Estimate 0.9-1.0).

Laryngeal cancer Nine papers reported a Risk Estimate for laryngeal cancer. From the papers which reported figures, it can be estimated that in excess of 1,387,369 person-years of follow-up contributed to this evidence. The estimates reported ranged from 0.37 to 13.48. It should be noted that this latter paper was the only study to present a statistically significant estimate, albeit one based on only three cases. It was also the only paper to report an estimate greater than 1.0. In this instance, it would seem appropriate to conclude that there is no apparent positive association between laryngeal cancer and the occupation of firefighter.

Lung cancer There were nineteen studies which reported a useable Risk Estimate for lung cancer. From those papers which reported figures, it can be estimated that in excess of 1,660,681 person-years of follow-up contributed to this evidence. The reported estimates ranged from 0.24 to 1.42. The former value was statistically significant as were those for two papers indicating an excess risk. On balance, it appears that there is no indication of any excess risk of lung cancer amongst firefighters, with a risk estimate considered unlikely to be very different from 1.0 (± 0.05).

Skin cancer Interpretation of the evidence relating to skin cancer is complicated by a certain lack of consistency between papers in the cancers covered by this term. Seventeen papers presenting a useable Risk Estimate were selected for this review. From those papers which reported figures, it can be estimated that in excess of 1,607,169 person-years of follow-up contributed to this evidence. The Risk Estimates reported ranged from 0.0 to 2.92, although the former figure is perhaps deceptive in that the study in question probably lacked sufficient sensitivity, reporting no cases where 1.1 were expected. The next lowest figure of 0.63 is probably therefore more informative. One paper reported a significantly reduced risk and four a significantly elevated risk. On balance, there would appear to be relatively recent consistency suggesting a positive association between firefighting and skin cancer, probably of the order of 1.3-1.4, but clearly less than 2.0.

Breast cancer There were very few papers which reported a Risk Estimate for breast cancer amongst firefighters. Three papers were selected, of which two gave separate estimates for male and female firefighters. However, these reported on mortality and morbidity amongst essentially the same cohort (that for mortality covering a larger time period). For males, useable Risk Estimates ranged from 0.51 to 7.41. The latter (mortality) study estimate was statistically significant. In excess of 945,688 person-years of follow-up contributed to these estimates. For females the mortality study yielded a Risk Estimate of 0.51 (17,548 person-years) and the morbidity study an estimate of 0.96 (18,843 person-years). Clearly, with such limited material, there is no consistent evidence of any generally elevated risk amongst firefighters.

Cervical cancer Only one study reported on cervical cancer. Although clearly the results from a single study must be treated with caution and, other than occupation, there can be many potential factors to account for this, the size of this finding (SIR=5.24, 2.93-8.65; 18,843 person-years) at least suggests a clear need for vigilance amongst the growing numbers of female firefighters in the UK.

Prostate cancer Seventeen papers reported a useable risk estimate for prostate cancer. One of these also reported an estimate for a cohort of black firefighters. From those papers which reported figures, it can be estimated that in excess of 1,665,249 person-years of follow-up contributed to this evidence. The Risk Estimates reported ranged from 0.31 to 2.61, both of which were statistically significant as was one other report of a reduced risk and three studies where a significantly elevated risk was reported. The estimate for black firefighters was also significant (1.9). On balance it appeared that there was an increased risk of prostate cancer amongst firefighters. Taking the relative size of the different studies into account it seemed that an estimate of 1.2-1.3 was reasonable.

Testicular cancer Eight studies were identified which reported useable Risk Estimates for testicular cancer. From those papers which reported figures, it can be estimated that in excess of 590,009 person-years of follow-up contributed to this

evidence. The estimates ranged from 1.15 to 8.2 and this latter value, and two others, were statistically significant. Previous reviews have suggested that the relative risk of testicular cancer amongst firefighters might approach 2.0. However, more recently published material tends to reinforce the view that, although there is a positive association between the incidence of testicular cancer and the occupation of firefighting, a value of less than 2.0 would seem appropriate. This is consistent with the summary review of Straif *et al* (2007) which indicates an average relative risk of 1.5 which would appear to be a reasonable estimate.

Bladder cancer Sixteen papers reported useable Risk Estimates for bladder cancer. From those papers which reported figures, it can be estimated that in excess of 1,619,174 person-years of follow-up contributed to this evidence. Estimates ranged from 0.23 (statistically significant) to 3.16. This latter value was not significantly greater than 1.0 although two other papers did report a significantly increased risk. On balance, the majority of studies favour a slight excess risk of bladder cancer, with the balance probably favouring a slightly increased estimate over that of 1.2 previously suggested, although possibly by as little as 5% (1.25).

Kidney cancer Thirteen papers were identified which reported a useable Risk Estimate for cancer of the kidneys. From those papers which reported figures, it can be estimated that in excess of 836,898 person-years of follow-up contributed to this evidence. The estimates given ranged from 0.23 to 4.14, both of which were statistically significant. However, the latter figure appeared to be a relative outlier and the next highest estimate of 1.44 (which was also statistically significant) would seem to be more informative. One other study reported a significantly elevated estimate. It would appear on balance that there is probably a marginal excess risk of kidney cancer amongst firefighters, giving a risk estimate of around 1.1-1.2, which is probably not statistically significant.

Ocular cancer Two incidence studies reported useable Risk Estimates of 1.54 and 5.2, based upon a total of 6 cases derived from a total of almost 450,000 person-years. Clearly, with only two papers, no clear conclusions can be derived for ocular cancer.

Brain cancer Seventeen papers were selected as providing useable Risk Estimates. From those papers which reported figures, it can be estimated that in excess of 1,303,607 person-years of follow-up contributed to this evidence. The published estimates ranged from 0.58 to 3.78, the latter and two others indicating a significantly elevated risk. Estimates of the likely scale of any effect with any precision is difficult, especially given recent, conflicting, results; but it would seem that, adding the data from the three recent studies to those included in previous reviews, a risk estimate for brain cancer amongst firefighters of the order of 1.2 (± 0.2) would seem likely.

Thyroid cancer There were five papers which reported useable Risk Estimates for thyroid cancer, although two of these were mortality and morbidity studies from essentially the same population. From those papers which reported figures, it can be estimated that in excess of 945,688 person-years of follow-up contributed to this evidence. Risk Estimates ranged from 0.58 to 4.82. Although statistically significant, the latter figure was something of an outlier and the morbidity estimate from the same cohort of 1.77 (which was also statistically significant) is probably more representative. Six registered cases amongst the female cohort from the latter paper gave a significant Risk Estimate of 3.97. Given the limited number of studies and the variation in reported estimates there is clearly therefore no consistent evidence to suggest any occupational relationship between firefighting and thyroid cancer.

Lymphatic and haemopoietic cancers Eight papers were identified which reported a useable Risk Estimate for lymphatic and haemopoietic cancers grouped together. From those papers which reported figures, it can be estimated that in excess of 311,816 person-years of follow-up contributed to this evidence. The estimates given ranged from 0.44 to 1.88 and one study suggested a significantly increased risk. From this material there is no consistent evidence to suggest anything more than a possibly modest positive association (1.1-1.2) between lymphatic and haemopoietic cancers and firefighting.

Hodgkin's disease Six papers were identified which reported a useable Risk estimate for Hodgkin's disease. From those papers which reported figures, it can be estimated that in excess of 1,059,696 person-years of follow-up contributed to this evidence. The estimates ranged from 0.23 (based on one case) to 2.4. This latter value was statistically significant. In addition, a significantly increased risk of cancer morbidity was reported in one study for female firefighters (6.25). On balance, from the various studies, there is no consistent evidence to suggest any elevation of risk of Hodgkin's disease amongst male firefighters and only the one study on which to base any estimate of risk to females.

Non-Hodgkin's Lymphoma A useable Risk Estimate for Non-Hodgkin's lymphoma was reported by thirteen papers. From those papers which reported figures, it can be estimated that in excess of 1,387,369 person-years of follow-up contributed to this evidence. Estimates ranged from 0.65 to 2.04 and, in two papers reporting smaller increases in risk the estimates were statistically significant. Thus, although early studies and reviews appeared to suggest a marked increase in risk of a diagnosis of non-Hodgkin's Lymphoma amongst firefighters, further, more recent studies have progressively suggested a diminution of that risk, such that current estimates would be less than a 20% increase, with some uncertainty as to whether that figure would be statistically significant.

Multiple myeloma Seven studies reported useable Risk Estimates ranging from 0.39 to 1.68 with one paper reporting a smaller but significant elevation of risk. From those papers which reported figures, it can be estimated that in excess of 353,912 person-years of follow-up contributed to this evidence. It appears from the evidence available that the most accurate estimate of risk is a positive association between firefighting and multiple myeloma with a risk ratio of the order of 1.4-1.5.

Leukemia Twelve papers presented useable Risk Estimates for Leukemia amongst firefighters. From those papers which reported figures, it can be estimated that in excess of 1,387,369 of observation contributed to this evidence. Estimates ranged from 0.61 to 1.90 although the latter is possibly misleading as it is based upon just one category of leukemia whilst most have included two. The next lowest estimate of 1.27 might therefore be more informative. On the evidence available it is unlikely that the overall risk estimate for leukemia and firefighting would be increased by more than a modest amount above previous estimates of around 1.1 and would certainly not exceed a value of 2.0.

Other ill-health

Rather fewer papers were identified which addressed forms of ill-health in firefighters other than cancer. The exceptions were probably the nine papers on each of coronary heart disease and respiratory health. However, the conclusions for these and the limited evidence in relation to other health effects are summarised below:

Coronary Heart Disease At the current time the research is inconclusive with regard to CHD and fire fighting.

Hearing loss There is evidence of hearing loss when firefighters are compared to control groups. However, further research is required to examine this further in those involved in general fire fighting specifically in the UK context.

Hip and knee osteoarthritis The results suggest that there is an increased risk of hip and knee osteoarthritis among firefighters. However, this is based on one study and further research is required to identify if this is common to all firefighters and specifically in the UK.

Mental health At the current time there is limited evidence in relation to mental health in firefighters mainly due to a lack of research within the UK and international context. Thus no measures of effect can be made at this time.

Respiratory health The evidence for fire fighting having a negative impact on respiratory health is inconclusive as the majority of the research is based on small cross-sectional studies. However, these studies indicate a potential effect but it is hoped that current practice in the use of PPE will ameliorate this.

Sarcoidosis At the current time no association between fire fighting and sarcoidosis can be made.

None of the reviews therefore identified a reliable summary risk estimate approaching the criterion of 2.0. For this reason, the other research questions raised:

Is any disease, thus identified, capable of definition and diagnosis with a reasonable degree of confidence?

Can any such doubling of risk be linked to a specific exposure associated with employment as a fire-fighter, and any defined duration or level of exposure?

How does international research compare with exposures found in the UK?

Is it plausible that there is an association between a disease and a specific exposure?

were not addressed.

1 INTRODUCTION

The Industrial Injuries Advisory Council (IIAC) invited the Institute of Occupational Medicine (IOM) to undertake a systematic review of the evidence relating to occupational health risks in fire-fighters, to assist the Council in advising the government on the prescription of industrial diseases.

It has long been recognised that operational firefighters are potentially exposed to a wide variety of potentially harmful substances or physical agents. Such exposures can occur through a variety of routes, including inhalation and skin contact, although advances in personal protection (e.g. clothing and breathing apparatus) have apparently served to reduce such exposures in recent years.

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. The working group identified considerable difficulties in reliably quantifying the potentially harmful exposures of firefighters but concluded by classifying occupational exposure as a firefighter as “possibly carcinogenic to humans (Group 2B)” (Straif *et al.*, 2007).

In addition to possible carcinogenetic exposures, other forms of ill-health might also be anticipated. For example, in relation to the potential respiratory health effects of the inhalation of smoke and other substances, Ribeiro *et al* (2009) recently reported a cross-sectional survey of respiratory ill-health (based on self-reported questionnaires). The authors concluded that firefighters displayed a higher prevalence of respiratory symptoms and asthma than did a comparison group of police officers. Conversely, because of selection procedures, firefighters are often considered to be an inherently healthier group than the general population. For example, as Rosenstock and Olsen (2007) point out, firefighters are less likely to die from coronary heart disease than the general population.

In order for a disease to be prescribed, it is not sufficient to demonstrate causation, especially where diseases can be multi-causal with factors other than occupation playing a role. The burden of proof is equivalent to that which applies in civil litigation, namely that it should be established as “more likely than not” that a disease occurred as a result of an occupational exposure. For example, in 2008, IIAC prepared a position paper in relation to one form of cancer, that of testicular cancer. This concluded that, while there was evidence of an increased risk of testicular cancer in fire fighters, there was insufficient evidence that risks are clearly doubled (more likely than not) and, at present therefore, insufficient evidence on which to recommend prescription (IIAC, 2008).

It is against this background that the present review was commissioned and prepared.

2 METHODOLOGY

2.1 QUESTIONS TO BE ADDRESSED BY THE REVIEW

Against the background outlined above, the review presented here was developed to identify evidence to address the following questions:

- 1) Are published epidemiological data indicative of a significantly increased risk of disease in those employed as a fire-fighter, and, if so, is this risk more than doubled compared to that in the general population?
- 2) Is any disease, thus identified, capable of definition and diagnosis with a reasonable degree of confidence?
- 3) Can any such doubling of risk be linked to a specific exposure associated with employment as a fire-fighter, and any defined duration or level of exposure?
- 4) How does international research compare with exposures found in the UK?
- 5) Is it plausible that there is an association between a disease and a specific exposure?

2.2 SEARCH STRATEGY

In developing the methodology for the review a search strategy was developed and is presented in Appendix A. Search terms were developed from initial scoping work and a final strategy agreed with the sponsor. A number of electronic databases were searched and are listed below.

Databases

Medline
PsychInfo
Science Citation Indexes

Websites were also searched, including the following list:

NIOSH
European Agency for Safety and Health
HSE

Searches were carried out and titles and abstracts (where available) were stored using Ref Works software.

2.3 SCREENING OF CANDIDATE PAPERS

On retrieval of titles and abstracts an initial screening process was carried out by the research team. Each publication was screened by a researcher with some knowledge of the subject area working to specified guidelines. Where the relevance of the paper was not apparent from the title or, where available, the abstract, a conservative approach was taken and full publications were ordered to allow full text scanning. If the reviewer was unable to make a decision based on the content of the title or the abstract, a second researcher would review the abstract to reach a mutual decision.

2.4 RETRIEVAL OF POTENTIALLY RELEVANT PAPERS

On completion of the screening process, potential publications were obtained for review and data extraction. Publications were retrieved by the IOM Information Scientist.

2.5 CRITICAL APPRAISAL, QUALITY ASSESSMENT AND DATA EXTRACTION

On receipt of full publications, papers were scanned further at initial acquisition to ensure they fitted the inclusion criteria. Those that were included were reviewed and data were extracted into a specifically developed spreadsheet. Guidance notes were prepared for the reviewers and can be seen in Appendix B. Each paper was reviewed and data extracted into the spreadsheet. A quality assessment was made of each paper based on the following

++	All or most of the criteria have been fulfilled. Where they have not been fulfilled the conclusions of the study or review are thought very unlikely to alter.
+	Some of the criteria have been fulfilled. Those criteria that have not been fulfilled or not adequately described are thought unlikely to alter the conclusions.
–	Few or no criteria fulfilled. The conclusions of the study are thought likely or very likely to alter.

Extracted data were then collated into evidence tables to support the narrative review.

Additional material, in the form of papers cited by those selected for review, was also obtained where relevant and added to the review.

Decisions were made with regard to papers that were excluded from the review. Appendix C is a collation of the papers that were excluded from the review and the reasons for their exclusion.

3 RESULTS

3.1 RESULTS OF SEARCHES

The searches across various different databases and websites yielded a total of 678 references for potential inclusion. The results from these searches were stored, with abstracts where available, in RefWorks software.

As provided for in the methodology, an initial screening assessment was carried out of these abstracts. As expected, the deliberately inclusive nature of the search terms resulted in many unsuitable papers being identified by the searches. For example, these would commonly include papers describing potential risks to health where the consequential outcomes would be identified within the search terms. As a result of this initial screening, 141 papers were flagged for further consideration and potential review. Again, the conservative strategy adopted meant that, where it was not possible to positively exclude a paper (for example where no abstract was available), it was retained for further evaluation.

Full papers were obtained of the selected material and, as a final check, papers were subjected to the same screening assessment to remove fundamentally unsuitable material. These were subjected to a standardised evaluation process using the procedure outlined above.

In some instances, particularly when considering other review papers, further references of potential relevance were identified which had not been identified through the search strategy. Where it seemed appropriate to do so from the context in which they were cited these were obtained and considered for inclusion. They were not unquestioningly included. For example, identified in this manner was that by Demers, *et al* (1992b), cited by LeMasters *et al* (2006) in their review of cancers. It transpired that the paper in question utilised data from a combined cohort of firefighters and police and it was not therefore included as further evidence in the current review.

Reviewing these papers resulted in the inclusion of material from 71 papers for the review.

3.2 FIRE FIGHTING AND CANCER

3.2.1 General Comments

A total of 34 papers which made reference to some association (positive or negative) between cancer of various types and the occupation of fire fighting were selected to provide material for consideration as part of the review. Of these papers, seven were themselves review articles and care was taken to avoid effective double-counting by including these and the primary data sources they utilised in their review. Similarly, these reviews tended to encompass broadly the same set of papers and it would be misleading therefore to regard each review as separate independent data sources.

Not all of the studies are mutually independent. Thus, although no direct information is available, it appears likely that some of the cohort of San Francisco firefighters, studied by (Beaumont *et al.*, 1991) went on to form part of the cancer registry study of Californian firefighters reported by (Bates, 2007) although the follow-up period for the former ceased (1982) before the onset of the registry in 1988. More significantly, the cancer incidence rates for Seattle and Tacoma firefighters between 1974 and 1989 reported by (Demers *et al.*, 1994) would clearly have overlapped with the mortality study in Seattle, Portland and Tacoma firefighters between 1945 and 1989. These would also, at least partly, probably been encompassed within the mortality study across 24 states of (Ma *et al.*, 1998) and that across 27 states of (Burnett *et al.*, 1994) although the years covered between these two differed slightly. It appears that most of the larger studies of US cohorts formed from specific groups (e.g. Florida, California and Massachusetts) were not however covered by these multistate studies. The mortality study of Ma *et al.* (2005) and the morbidity study the following year (Ma *et al.*, 2006) had a clear commonality of the cohort used. (Sama *et al.*, 1990) and (Kang *et al.*, 2008) both studied cancer morbidity amongst Massachusetts firefighters although the reference periods (1982-1986 and 1987-2003) differed. Where there was a considerable overlap in source material then the less inclusive paper was not included. An example of this would be that by Heyer *et al.* (1990) which presented material from a Seattle cohort, but was excluded in favour of the papers by Demers *et al.* (1992 and 1994) covering Seattle with other cities.

Some other papers were notable in that they presented studies of reviews of occupations and cancer which did not make any reference to fire fighting amongst the featured occupations. An example of this would be the study of cancer registrations in New Zealand for incidences of testicular cancer, reported by (Pearce *et al.*, 1987). Clearly, this can be interpreted as a negative study, failing to demonstrate any association between fire fighting and testicular cancer. However, it is possible that the study lacked sufficient sensitivity to identify any relationship which might have existed, given that, during the period in question, the authors estimate an age-standardised incidence rate of 3.5 cases per 100,000 person-years at risk. With an average of around 2,300 firefighters at any time (Bates *et al.*, 1995) it is clear that fewer than three cases would be expected across the three decades of the study. The authors only reported occupational groups with at least 10 cases and would not therefore have reported such a small cohort, even had there been any elevated risk. For this reason, such papers have not been routinely included unless the form of cancer in question was specifically reported

In presenting the findings graphically, results variously cited as SMRs as a percentage have been converted to ratios to provide a common base for display. The parameter used in each case is however quoted in any textual presentation of the values obtained. Whilst Odds Ratios and SMRs differ slightly in their calculation the resultant differences are considered to be negligible for relatively rare events.

For these graphs, the analysis drawn from the main comparison of any study, as opposed to any sub-cohort analysis, has been used to maximise comparability between studies.

A number of studies utilised a cohort derived from those employed as police as the comparator for determining mortality or morbidity ratios e.g. (Kang *et al.*, 2008). Such studies argue that the selection procedures and other factors relating to the occupation of policeman (or woman) create similar starting cohorts in the two groups and that the police therefore present a more appropriate comparator. It is not clear whether or not this is an appropriate view but it is certainly one endorsed by a number of other research groups. However, in the context of possible prescription, it is assumed that the appropriate comparison would be against the general population and this material, rather than that from alternative comparators, has been used throughout the present review.

In 1996, a report was published on mortality and cancer incidence amongst UK firefighters, based upon a cohort drawn from five English brigades (Donnan, 1996). Mortality is only reported for lung cancer with other forms of cancer limited to the incidence registry. The basis for selection of the individual cancers reported is not given, although it is noted that named cancers represent two-thirds of all cancer registrations and that the least common (prostate cancer) had 8 cases, which represented 4% of all cancers. It is possible therefore that there were too few incidences of other forms of cancer for meaningful reporting.

Not all of the papers reviewed quoted the calculated years of follow-up (or equivalent) for the group studied. In some instances, the nature of the study (e.g. a cancer registry study) made this inappropriate whilst, in other papers, although apparently determined, the value was not reported. The information available is summarised in respect of each form of cancer reported below.

3.2.2 Cancers of the Lip, Oral Cavity and Pharynx

This category of cancers is not always clearly applied in the various epidemiological studies identified. Thus some authors refer separately to the lip, tongue, etc, and others refer specifically to those affecting the pharynx. For this element of the review, those relating to the oral (buccal) cavity and the pharynx have been combined, as most authors cluster together these and the lip as ICD 9 codes 140-149 or ICD 10 codes C00-C14. Amongst those who specified the codes used, the paper by Aronson *et al* (1994) was restricted to 146-149 and Kang *et al* utilised three categories: lip (given separately in this review); buccal cavity; and nasopharynx, which have been presented together in this section.

Eight risk estimates (with confidence intervals) have been presented for this review and are shown in Figure 1. The two findings from Kang *et al* (2008) suggest a quandary in that the two risk estimates appear to be diametrically opposed although, as can be seen by the large confidence intervals, especially for cancer of the nasopharynx, not too much emphasis should be placed on these findings. This pattern is not, for example, shown in the breakdown of cancer sites reported by Beaumont *et al* (1991) (not shown), who reports very similar estimates for the tongue (1.06, 0.13-3.86) and pharynx (1.17, 0.32-3.00). The combined data from this paper shows the largest estimate (1.43, 0.71-2.57) although it should be noted that this includes the two cases of cancer of the lip with a separate risk ratio of 6.17 (0.75-22.29) within the cluster of 11 deaths. Clearly any effect is not huge and, given the wide confidence intervals on all component studies, any summary estimate is unlikely to differ significantly from 1.0.

The meta-analysis of LeMasters *et al* (2006) identified nine analyses in formulating a summary of Risk Estimate of 1.23 (0.96-1.35). Most of these papers, with the exception of general mortality studies, have been included in the present review. One exception is the paper by (Demers, *et al.*, 1992b) which the authors included despite the fact that the cohort studied appears to have been a combined cohort of firefighters and police; and despite the considerable overlap between this and the paper by Demers *et al* (1992), which included data from the same two cities plus a third, covering the same follow-up period. Other papers cited include: Giles *et al* (1993), from which no appropriate risk estimate can be found in the source paper; and an estimate for lip cancer alone from Ma *et al* (1998). This latter paper presents a category for the nasopharynx but reports no cases for white firefighters. Arguably it would have been more appropriate to have combined the observed and expected values for these two categories in deriving a risk estimate to carry forwards. Clearly therefore this summary estimate should be viewed with caution.

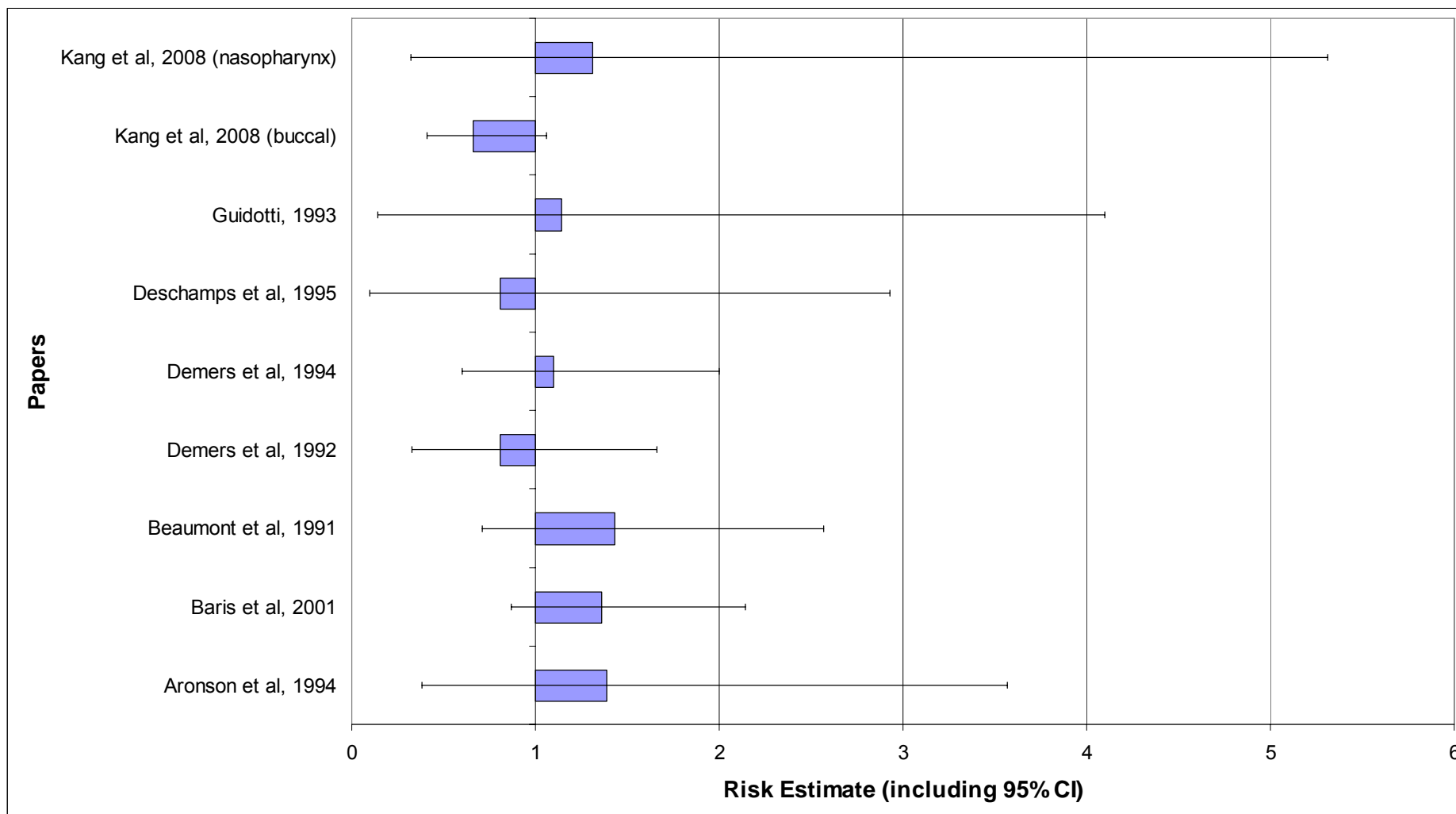
The more recently published paper of Kang *et al* (2008) presents a complicated picture because of its division of this group of cancers into three component parts. With a far greater number of incident cases (21), cancer of the buccal cavity would presumably carry more weight in any calculation and, with an SMOR of 0.66 (0.41-1.06) would clearly reduce any summary estimate.

Of the eight papers, six presented an estimate of person-years of follow-up (or equivalent). These totalled 553,161 person-years.

Given the apparent initial over-estimate, through the inclusion of the data on lip cancer from Ma *et al* (1998) and the likely further reduction from this most recent data, it is likely that a risk estimate of 1.0-1.1 would seem reasonable, scarcely distinguishable from 1.0.

As a final note, Ma *et al* (1998) did identify a sizeable and significant excess of nasopharyngeal cancers amongst black firefighters (7.6, 1.3-46.4). However, these headline values obscure the fact that this is derived from a single case, counselling caution in considering this finding.

The evidence for cancers of the lip, oral cavity and pharynx is given in Table 1.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 1: Comparisons of relative risks (with 95% confidence intervals) for cancers of the lip, oral cavity or pharynx, derived from published studies

Table 1. Evidence relating to fire fighting and cancers of the lip, oral cavity or pharynx

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were 4 deaths attributed to cancer of the pharynx (ICD 9, 146-149) in the cohort, yielding a non-significant SMR of 139 (38-357). Further analysis by years since first employment, as a surrogate for exposure, superficially yielded an apparent trend but the small numbers of death and consequently large confidence intervals mean this is unlikely to be meaningful. (<20 years, SMR=0, 0-946); 20-29 years, SMR=122, 3-680; >=30 years, SMR=181, 37-528).

Baris *et al.*, 2001 Mortality from cancer and other causes amongst a cohort of 7,789 FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; 1.18-1.93) and IHD (SMR=1.09; 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; 1.11-2.63); colon cancer (SMR=1.94; 1.38-2.73); multiple myeloma (SMR=2.54; 1.15-5.67); benign neoplasms (SMR=2.95; 1.41-6.19); & IHD (SMR=1.14 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 1.03-7.33); circulatory diseases (SMR=1.27; 1.05-1.52); & IHD (SMR=1.33; 1.06-1.65). Several others were elevated but ns. No consistent pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations. ++

19 deaths attributed to cancer of the buccal cavity and pharynx (ICD 9, 140-149) yielded an SMR of 1.36 (0.87-2.14) although this was non-significant. In the analysis of duration of employment as a surrogate for exposure there was no apparent trend across the three categories. (≤ 9 years, SMR=1.15, (0.43-3.07); 10-19 years, SMR=1.83, (0.95-3.51); ≥ 20 years, SMR=1.09; (0.50-2.43)). As an alternative measure of exposure, company type yielded some differences consistent with the suggestion that members of one sub-cohort would have been likely to have received greater exposure to possibly toxic substances. (engine company: SMR=2.00, (1.11-3.63); ladder company: SMR=0.91, (0.13-6.44); both ladder and engine companies: SMR=0.72, (0.30-1.73)). Year of hire also showed a pattern of higher mortality amongst those recruited earlier. (pre-1935: SMR=2.11, (1.13-3.91); 1935-1944: SMR=0.87, (0.33-2.32); post 1944: SMR=1.10, (0.46-2.64)).

Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	Presented pooled data for buccal cavity and pharynx and separated for lip, tongue and pharynx. (BC&P: Rate Ratio (RR)=1.43, 0.71-2.57: Lip: RR=6.17, 0.75-22.29; Tongue: RR=1.06, 0.13-3.86; Pharynx: RR=1.17, 0.32-3.00). No exposure-related data were presented for this group of cancers.
Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 1.1-3.6) and leukaemia (SMR=2.6; 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Oral and pharyngeal cancers (ICD 9, 140-149) had an SMR=0.81 (0.33-1.66). This group of cancers did not feature in analysis by duration of exposed employment, years since first employment, or age at risk.
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident in Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 1.1-1.7), as was stomach cancer (SIR 1.4; 0.6-2.7) and ocular melanoma (SIR=5.2; 0.6-18.8). The risk of colon cancer (SIR=1.1; 0.7-1.6) was slightly elevated compared to the general population.	++	Oral and pharyngeal cancers (ICD 9, 140-149) had a SIR=1.1 (0.6-2.0) relative to local county rates. An analysis by duration of exposed employment did not show any systematic pattern: <10 years: SIR=1.4, (0.2-5.1); 10-19 years: SIR=2.5, (0.7-6.4); 20-29 years: SIR=0.3, (0.0-1.2); 30+ years: SIR=3.9, (0.8-11). Similarly there was no pattern to the results from a breakdown by years since first employment: < 20 years: SIR=1.5, (0.0-8.2); 20-29 years: SIR=0.5, (0.0-2.7); 30+ years: SIR=1.3, (0.6-2.4).

Deschamps <i>et al.</i> , 1995	Cohort of 830 firefighters with a minimum service of five years, studied over a 14 year period from Jan 1977 to Jan 1991. When compared to the average French male, the Paris fire-fighters were found to have a far lower overall mortality (SMR = 0.52, 0.35-0.75). None of the cause specific SMRs were significantly different from unity. However a greater number of deaths than expected was observed for genitourinary cancer (SMR = 3.29), digestive cancer (SMR = 1.14), respiratory cancer (SMR = 1.12) and 'cerebrovascular disease' (SMR = 1.16). The low overall SMR observed was consistent with the healthy worker effect.	+	Pharyngeal cancer (ICD 9 140-149) had an SMR=0.81, (0.10-2.93). No exposure-related analysis was reported in this study.
Guidotti 1993	Cause of death was examined for two cohorts totalling 3,328 firefighters from Edmonton & Calgary (Alberta) in Canada. The firefighters were active from 1927-1987. Data was analysed over the entire cohort; by entry date; for latency as years since entry; and for duration of employment. Mortality from all causes was close to expected (SMR=96, 87-107) as was that for heart disease (SMR=110, 92-131). Statistically significant excesses were observed for: all malignant neoplasms (SMR=127, 102-155); kidney & ureter cancers (SMR=414, 166-853); and mental disorders (SMR=455, 274-711). Only isolated excesses were apparent from any of the latency or exposure-related analyses.	++	Oral cancers (ICD 9 140-149) had an SMR=114, (14-410) but did not feature in any breakdown analyses by entry date or other exposure surrogates.
Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Cancers of the nasopharynx had an SMOR=1.31, (0.32-5.31) but, with only three deaths, these cancers did not feature in any further analysis. Cancer of the lip had an SMOR of 1.05 (0.33-3.30), based on four deaths. Again, no further breakdown was presented for this form of cancer.
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The meta-analysis across all forms of study, utilising a total of nine analyses, yielded a Summary Risk Estimate of 1.23 (0.96 –1.55) for cancer of the buccal cavity and pharynx. This was slightly higher than the meta-SMR of 1.18, (0.81–1.66) and the heterogeneity of the data was not significant at the 10% level.

Ma *et al.*, 1998 +
 A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 1.1-1.2), lip (MOR=4.9; 1.9-18.3), pancreas (MOR=1.2; 1.0-1.5), bronchus and lung (MOR=1.1; 1.0-1.2), soft tissue sarcoma (MOR =1.6; 1.0-2.7), melanoma (MOR=1.4; 1.0-1.9), prostate (MOR=1.2; 1.0-1.3), kidney and renal pelvis (MOR=1.3; 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 3.0-16.0), colon cancer (MOR=2.1; 1.1-4.0), prostate cancer (MOR=1.9; 1.2-3.2) and nasopharynx (MOR=7.6; 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.

The results did not identify any deaths due to cancer of the nasopharynx for white firefighters. However, lip cancers yielded a MOR=5.9, (1.9-18.3). For black firefighters an excess risk was identified for cancer of the nasopharynx (MOR=7.6; 1.3-46.4) although this was only based on a single death. There were no deaths from cancer of the lip amongst this sub-cohort.

3.2.3 Lip Cancer

Only three papers (Beaumont *et al*, 1991; Ma *et al*, 1998; Kang *et al*, 2008) reported lip cancer separately from nasopharyngeal cancers. They were based on a very small data set (a total of nine deaths collectively) with consequently very wide confidence intervals, two of which suggested a large positive effect and the third (with the narrowest confidence interval) a risk ratio very close to one. There is not therefore sufficient evidence on which to base a specific conclusion on this form of cancer. However, lip cancer was included in a cluster of cancers considered by some authors as described above. The evidence relating to lip cancer is given in Table 1 relating to the cluster of cancers.

3.2.4 Oesophageal Cancer

Twelve papers were identified which presented risk estimates with confidence intervals for oesophageal cancer. These are shown in Figure 2. They show a considerable scatter of (largely) statistically non-significant estimates ranging from an estimate of less than half the risk compared to the general population (Aronson *et al*, 1994; SMR=40, 5-143) up to one of more than twice the risk (Beaumont *et al*, 1991; Risk Ratio=2.04, 1.05-3.57). This latter estimate, and another estimate of a positive risk (Bates, 2007: OR=1.48, 1.14-1.91) were significantly different from 1.0 as was the estimate of a negative association reported by Kang *et al* (2008) (SMOR=0.64, 0.47-0.87). Another feature of interest is the mismatch within the two studies reported by Demers and co-workers with the mortality study (1992a) showing a negative risk (SMR=0.81, 0.33-1.66) and the morbidity study a positive risk (SIR=1.1, 0.6-2.0) although neither are statistically significant and both based on relatively few cases (7 and 11 respectively). The mortality study does however cover a much wider time-period (1945-89 compared to 1974-89) and it is possible that there has been a relatively recent increase in incidence.

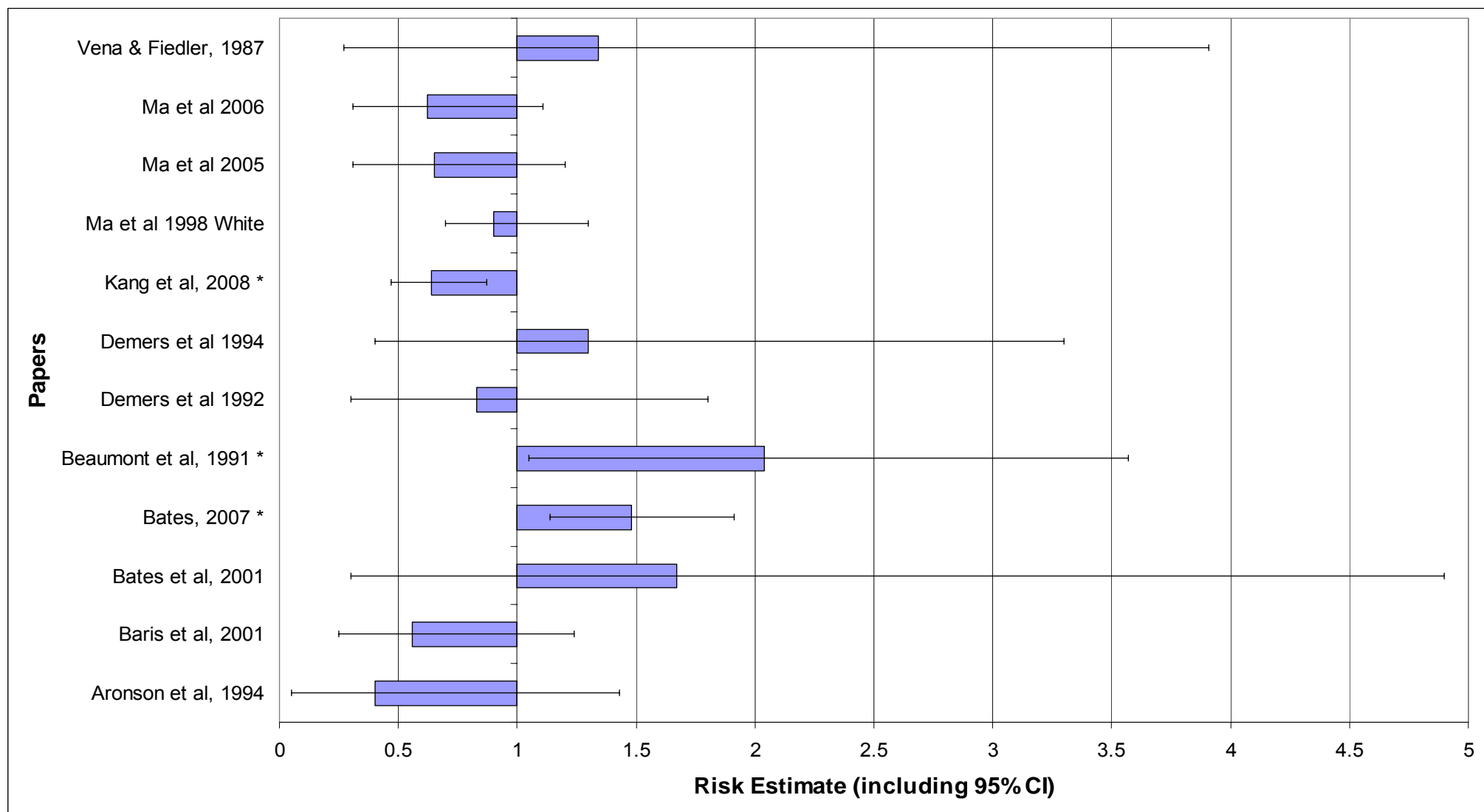
The estimates in the recent study by Kang *et al* (2008) and the earlier mortality study by Ma and colleagues (1998), together with the morbidity study of Bates (2007) are particularly powerful, being based on 57, 37 and 62 cases respectively, with most of the others derived from deaths/incidences in single figures.

Clearly, with only a single study presenting an estimate greater than 2.0, any summary estimate will not exceed this criterion level. On balance, a slight excess of the order of 1.2, would seem plausible from these figures.

Of the 12 papers, eight presented an estimate of person-years of follow-up (or equivalent). These totalled 1,483,206 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

Two systematic reviews addressed oesophageal cancer: Golden *et al* (1995) and LeMasters *et al* (2006). The former only presented data in summary form, indicating that there were equal numbers of papers with positive and negative findings, with three papers cited for each. LeMasters *et al* (2006) used eight analyses in deriving a summary Risk Estimate of 1.16 (0.86-1.57). This included the firefighter/police cohort study of Demers, *et al* (1992b) which had a lower incidence risk estimate than the later firefighter cohort of Demers *et al* (1994) (SIR=1.06, 0.34-2.47 compared to SIR=1.3, 0.4-3.3). However, it excluded the two more recent studies of Ma and co-workers (2005 and 2006) (both of which suggested negative associations); the study of Bates (2007) with a significant positive association; and that of Kang *et al* (2008) with a significant negative association.

Accommodating these estimates in revising that of LeMasters and colleagues is difficult, because of the conflicting findings. It is likely however that an estimated risk ratio of 1.1-1.2 would seem appropriate although unlikely to attain statistical significance.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 2: Comparisons of relative risks (with 95% confidence intervals) for oesophageal cancer, derived from published studies

Table 2. Evidence relating to fire fighting and oesophageal cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	<p>Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.</p>	++	<p>There were two deaths attributed to cancer of the oesophagus (ICD 9, 150) in the cohort, yielding a non-significant SMR of 40 (5-143). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of these deaths.</p>

Baris <i>et al.</i> , 2001	Mortality from cancer and other causes amongst a cohort of 7,789 FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No consistent pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations.	++	Six deaths attributed to cancer of the oesophagus (ICD 9, 150) yielded an SMR of 0.56 (0.25-1.24) although this was non-significant. In the analysis of duration of employment as a surrogate for exposure there was no apparent trend across the three categories: (≤ 9 years, SMR=0; 10-19 years, SMR=0.82, (0.26-2.52); ≥ 20 years, SMR=0.65; (0.21-2.02)). As an alternative measure of exposure, company type did not yield any meaningful results consistent with the suggestion that members of one sub-cohort would have been likely to have received greater exposure to possibly toxic substances than any other. (engine company: SMR=0.70, (0.23-2.19); ladder company: SMR=0; both ladder and engine companies: SMR=0.56, (0.18-1.7)). Year of hire also failed to showed any particular pattern of mortality (e.g. amongst those recruited earlier). (pre-1935: SMR=0; 1935-1944: SMR=0.55, (0.14-2.20); post 1944: SMR=1.12, (0.42-2.99)).
Bates <i>et al.</i> , 2001	This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).	+	In the whole-period analysis (1977-1996) cancer of the oesophagus had an SIR=1.67 (0.3-4.9) based upon three cancers. However, over the shorter period for which there was considered to be more complete data (1990-1996), there were two such cancers yielding an SIR=1.80 (0.2-6.5). Analysis of the data by years of paid service only did not feature this cancer and no mortality was reported.

Bates 2007	Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).	+	The occupation of fire-fighting was significantly associated with oesophageal cancer (Odds Ratio=1.48, 1.14–1.91). Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988-1995 and 1996-2003. Although both Odds Ratios were elevated, only that for the more recent registrations was significantly so (OR=1.36, 0.67-2.78 and OR=1.86, 1.10-3.14 respectively).
Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for cancer of the oesophagus was significantly elevated (2.04, 1.05-3.57). Exposure-related data for this cancer did not include confidence intervals. Although statistical significance was indicated where appropriate none of the values for oesophageal cancer achieved significance. Time since first employment: 3-19 years: RR=5.22; 20-29 years: RR=1.41; 30-39 years: RR=2.34; 40+ years: RR=1.55. Length of employment: 3-9 years: RR=0.00; 10-19 years: RR=3.47; 20-29 years: RR=2.10; 30+ years: RR=1.82.

Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Oesophageal cancer had an SMR=0.83 (0.30-1.80). This cancer did not feature in any of the analyses for surrogates of exposure.
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Oesophageal cancer had an SIR=1.3 (0.40-3.3). An analysis by years since first employment showed no particular pattern: < 20 years: SIR=0.0 (0.0-36.5); 20-29 years: SIR=4.3 (0.5-15.4) 30+ years SIR=0.8 (0.1-2.8).
Golden <i>et al.</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain,; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	States that there were equal numbers of papers with positive and negative findings for any association between firefighting and oesophageal cancer, with three papers cited for each. No summary risk estimate is presented.

Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Cancer of the oesophagus yielded an SMOR=0.64 (0.47-0.87) which was significantly lower than all other occupations. However, this negative association was not apparent in the age-stratified data: 18-54: SMOR=1.30 (0.52-3.24); 55-74: SMOR=0.70 (0.41-1.20); 75+: SMOR=1.58 (0.56-4.42).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The meta-analysis across all forms of study, utilising a total of eight analyses, yielded a Summary Risk Estimate of 1.16 (0.86 –1.57) for cancer of the oesophagus. This was higher than the meta-SMR of 0.68, (0.39–1.08) and the heterogeneity of the data was not significant at the 10% level.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, cancer of the oesophagus had an MOR=0.9 (0.7-1.3). For black firefighters the MOR was 1.4 but there were insufficient deaths (4) for a confidence interval to be computed.

Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk of atherosclerotic heart disease (3.85; 1.66-7.58).	++	Ten deaths from oesophageal cancer amongst the male cohort yielded an SMR=0.65 (0.31-1.20). No deaths from this cancer were recorded amongst the female cohort. A subsidiary analysis of firefighters with the longest estimated exposure (registered 1972-1976) gave a very similar outcome with SMR=0.55 (0.22-1.14).
Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	Eleven registered cases of oesophageal cancer amongst the male cohort yielded an SIR=0.62 (0.31-1.11). No cases of this cancer were recorded amongst the female cohort.
Vena <i>et al.</i> , 1987	A mortality study of all full-time municipal employees of Buffalo USA for a minimum of 5 years between 1950 and 1979. Individuals who had worked at least one year as a firefighter were included covering 1,867 white male firefighters (including 890 currently employed), 740 retirees, 65 who had resigned and 172 who died in service. Firefighters had significantly more benign neoplasms (SMR=4.17; 95% CI 1.34-9.73), malignant neoplasms including colon cancer (SMR=1.83; 95% CI 1.05-2.97), and bladder cancer (SMR=2.86; 95% CI 1.30-5.40).	++	Three deaths from oesophageal cancer amongst the cohort yielded an SMR=1.34 (0.27-3.91). Cancer of the oesophagus did not feature in subsidiary analyses of firefighters with estimates of exposure.

3.2.5 Stomach Cancer

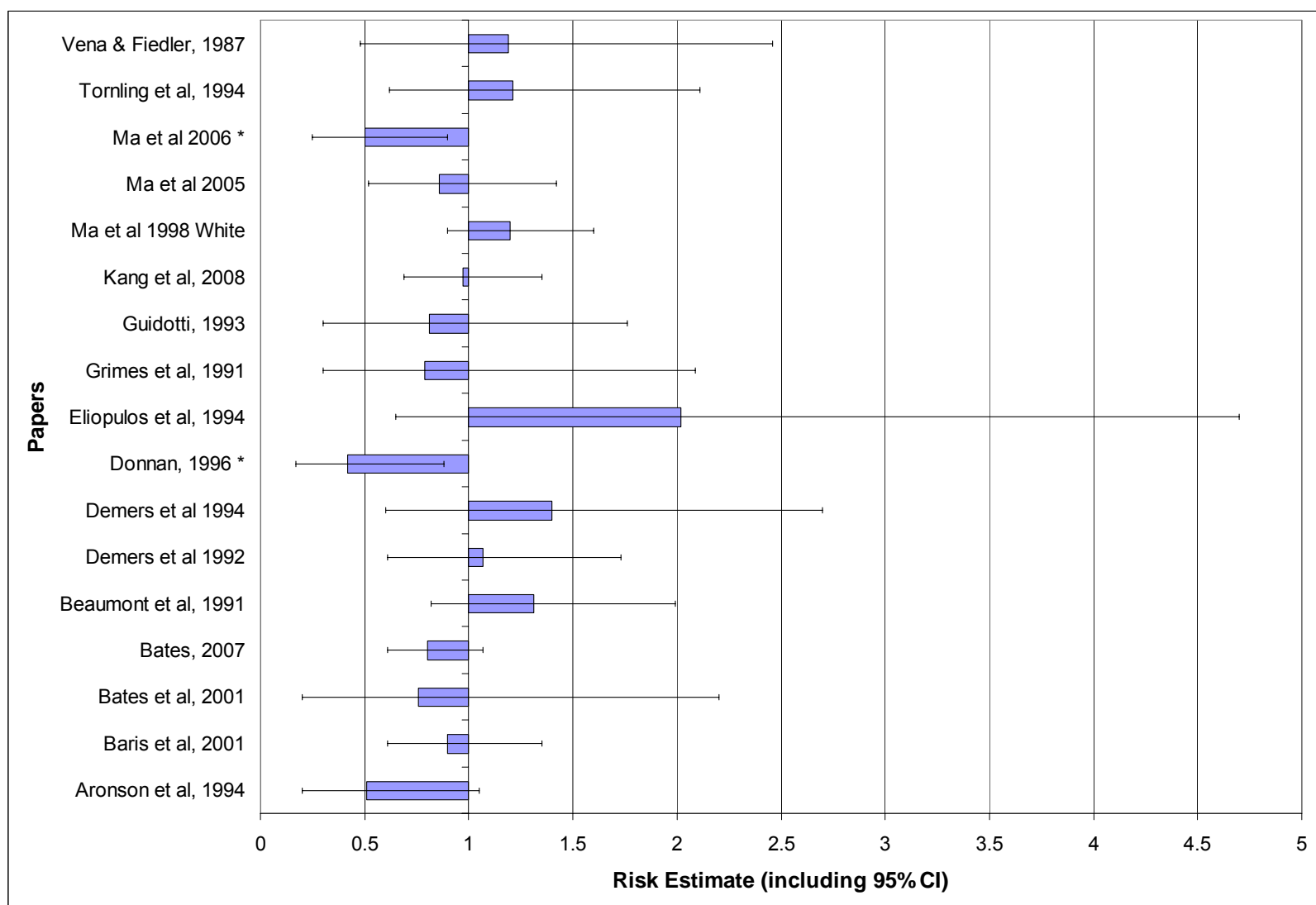
Of the 17 papers from which data were extracted for the current review, illustrated in Figure 3, two morbidity studies (Donnan, 1996; Ma *et al*, 2006) showed significant effects which, in both cases, was a significantly reduced risk of being diagnosed with stomach cancer if you were a firefighter (SRR=0.42, 0.17-0.88; SIR=0.50, 0.25-0.90 respectively) based on 11 and 14 incident cases. The parallel mortality study of Ma and co-workers (2006) also showed a reduced risk, but in this instance it was not statistically significant (SMR=0.86, 0.52-1.42). No other studies showed a significant effect and were reasonably evenly divided. One paper (Eliopoulos *et al*, 1994) reported a risk estimate slightly over two (SPMR=2.02, 0.65-4.70) based on five deaths. In contrast, Aronson *et al* (1994) reported a halving of risk (SMR=51, 20-105) based on seven deaths. Clearly, there is no consistent evidence either way, with the various studies tending to cancel one another out although, with two statistically significant studies, the tendency if anything would appear to be for a marginally negative effect.

Of the 17 papers, 12 presented an estimate of person-years of follow-up (or equivalent). These totalled 1,726,255 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

Golden *et al* (1995) reviewed seven studies reporting on stomach cancer, stating that most found a positive (but non-significant) association with firefighting. However, this included some double-counting of the Seattle cohort studied by Demers and colleagues (1992a & 1994). Although the authors included most of the older studies cited in the present review they did not include the negative study by Grimes *et al* (1991) nor, obviously, the predominantly negative studies published since that time.

LeMasters *et al* (2006) reported a summary Risk Estimate of 1.22 (1.04-1.44) based on 13 analyses, which again excluded the more recent papers of Ma *et al* (2003 and 2006); Bates (2007), and Kang *et al* (2008), together with the UK cohort study of Donnan (1996), which all reported negative associations. In addition, the erroneous inclusion of the firefighter/police cohort of Demers, *et al* (1992b) would have further inflated the estimate, as this paper reported a higher SIR than the firefighter-only cohort (1.75 vs 1.4). These factors would clearly reduce the summary estimate of risk towards 1.0 and, given the previously marginal significance, probably result in a confidence interval spanning 1.0. This reinforces the view that there is little or no substantive association between stomach cancer and being a firefighter.

The evidence relating stomach cancer and the occupation of firefighting is given in Table 3.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 3: Comparisons of relative risks (with 95% confidence intervals) for stomach cancer, derived from published studies

Table 3. Evidence relating to fire fighting and stomach cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were seven deaths attributed to cancer of the stomach (ICD 9, 151) in the cohort, yielding a non-significant SMR of 51 (20-105). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of these deaths.

Baris <i>et al.</i> , 2001	Mortality from cancer and other causes amongst a cohort of 7,789 FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No consistent pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations.	++	Twenty four deaths attributed to cancer of the stomach (ICD 9, 151) yielded an SMR of 0.90 (0.61-1.35) although this was non-significant. In the analysis of duration of employment as a surrogate for exposure there was no linear trend across the three categories: (≤ 9 years, SMR=0.55 (0.21-1.48); 10-19 years, SMR=1.39., (0.83-2.35); ≥ 20 years, SMR=0.65; 0.29-1.44). As an alternative measure of exposure, company type did not yield any meaningful results consistent with the suggestion that members of one sub-cohort would have been likely to have received greater exposure to possibly toxic substances than any other. (engine company: SMR=0.91, (0.49-1.68); ladder company: SMR=1.85 (0.69-4.92); both ladder and engine companies: SMR=0.64, (0.32-1.3)). Year of hire also failed to showed any particular pattern of mortality (e.g. amongst those recruited earlier). (pre-1935: SMR=1.19 (0.74-1.92); 1935-1944: SMR=0.60, (0.74-1.92); post 1944: SMR=0.54, (0.18-1.67)).
Bates <i>et al.</i> , 2001	This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).	+	In the whole-period analysis (1977-1996) cancer of the stomach had an SIR=0.76 (0.2-2.2) based upon three cancers. Over the shorter period for which there was considered to be more complete data (1990-1996), there were two such cancers yielding a very similar SIR=0.89 (0.1-3.2). Analysis of the data by years of paid service only did not feature this cancer. Mortality over the whole period had an elevated but non-significant SMR=1.16 (0.2-3.4).

Bates 2007	Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as the occupation in which they were been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Firefighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).	+	The occupation of fire-fighting was not significantly associated with stomach cancer (Odds Ratio=0.80, 0.61–1.07), based on 51 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988-1995 and 1996-2003. This yielded dichotomous results with the older registrants showing an excess OR=1.31 (0.75-2.99) and younger registrants fewer cases than expected OR=0.64 (0.3-1.36) although neither of these were significant.
Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for cancer of the stomach was elevated, but not significantly (1.31, 0.82-1.99), based on 22 deaths. Exposure-related data for this cancer did not include confidence intervals. Time since first employment: 3-19 years: RR=1.31; 20-29 years: RR=0.26; 30-39 years: RR=0.91; 40+ years: RR=2.32. The latter value was statistically significant. Length of employment: 3-9 years: RR=1.56; 10-19 years: RR=1.15; 20-29 years: RR=1.03; 30+ years: RR=1.67. None of these values achieved significance.

Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Stomach cancer had an SMR=1.07 (0.61-1.73) based on 16 deaths. This cancer did not feature in any of the analyses for surrogates of exposure.
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Stomach cancer had an SIR=1.4 (0.60-2.7) based on 8 incident cases. An analysis by duration of exposed employment showed no particular pattern: <10 years: 3.0 (0.4-11); 10-19 years: 1.2 (0.0-6.9); 20-29 years: 1.1 (0.3-2.9); 30+ years: 1.4 (0.0-8.1). A similar analysis by years since first employment also showed no particular pattern: <20 years: SIR=0.0 (0.0-15.7); 20-29 years: SIR=2.3 (0.3-8.3); 30+ years: SIR=1.3 (0.5-2.8).

Donnan, 1996	This reported the study of mortality and cancer incidence amongst a UK cohort of 5,568 firefighters drawn from five Brigades and compared against statistics for adult males from England and Wales. The cohort was followed for approximately 30 years (1965-1993). With few exceptions, deaths from the various causes studied were significantly lower than expected. This included deaths from all causes: SMR=0.67 (0.62-0.72); all circulatory diseases: SMR=0.70 (0.60-0.80); CHD: SMR=0.72 (0.61-0.85); all cancers: SMR=0.72 (0.60-0.86); and lung cancer: SMR=0.47 (0.32-0.67). Cancer registrations were also generally significantly lower with specific Standardised Registration Ratios (SRR) of: skin cancer: SRR=0.63 (0.39-0.97); lung cancer: SRR=0.24 (0.14-0.40); colon and rectal cancer: SRR=0.56 (0.32-0.93); bladder cancer: SRR=0.72 (0.36-1.26); stomach cancer: SRR=0.42 (0.17-0.88); and prostate cancer: SRR=0.31 (0.10-0.72).	++	Based on 11 registered cases, registrations of stomach cancer SRR=0.42 (0.17-0.88), were significantly lower than the England and Wales statistic. Stomach cancer did not feature in any sub-group analysis reported.
Eliopoulos <i>et al</i> 1984	973 fire fighters employed by the Western Australian Fire Brigade between 1 October 1939 and 31 December 1978 were successfully followed up to 31 December 1978. Mortality from all causes was less than expected (SMR=0.80, 0.67 to 0.96). No specific causes of death attained statistical significance and there were no indications that mortality was associated with duration of employment.	++	The SPMR for cancer of the stomach, based on five deaths, was 2.02 (0.65-4.70). There was no sub-cohort analysis of these deaths reported.
Golden <i>et al</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and some of the research. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain; haemopoietic and lymphatic (leukaemia; non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	States that most of the studies found (7 papers) reported a positive association between firefighting and stomach cancer but none were statistically significant. No summary risk estimate is presented.

Grimes <i>et al</i> 1991	A twenty year Proportionate Mortality study was conducted with all male firefighters in the City of Honolulu from 1969-1988 who had at least one year of service. This covered 205 deaths. Significant increases in risk of death were found for brain cancer (ICD 9, 191-192) (PMR=3.78, 1.22-11.71); prostate cancer (ICD 9 185) (PMR=2.61, 1.38-4.97); and cirrhosis of the liver (ICD 9 571) (PMR=2.3, 1.21-4.37). It was suggested that the latter could, at least in part, be attributed to an excess of alcohol consumption in this group. A significant decrease in mortality was observed for respiratory diseases (ICD 9 460-519) (PMR=0.37, 0.17-0.81).	+	The PMR for stomach cancer (ICD 9, 151) was 0.79 (0.30-2.09) based upon 4 deaths. A subsidiary analysis for firefighters of Caucasian or Hawaiian extraction yielded values of 1.17 (0.17-8.20) and 0.76 (0.19-3.01) based upon one and two deaths respectively.
Guidotti, 1993	Cause of death was examined for two cohorts totalling 3,328 firefighters from Edmonton & Calgary (Alberta) in Canada. The firefighters were active from 1927-1987. Data was analysed over the entire cohort; by entry date; for latency as years since entry; and for duration of employment. Mortality from all causes was close to expected (SMR=96, 87-107) as was that for heart disease (SMR=110, 92-131). Statistically significant excesses were observed for: all malignant neoplasms (SMR=127, 102-155); kidney & ureter cancers (SMR=414, 166-853); and mental disorders (SMR=455, 274-711). Only isolated excesses were apparent from any of the latency or exposure-related analyses.	++	The SMR for stomach cancer (ICD 9, 151) was 80.9 (29.7-176.0) based on six deaths. No further analyses of these deaths were reported.
Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Cancer of the stomach yielded an SMOR=0.97 (0.69-1.35) based on 46 registrations. No trend was apparent in the age-stratified data: 18-54: SMOR=2.02 (0.57-7.15); 55-74: SMOR=0.73 (0.41-1.27); 75+: SMOR=0.94 (0.38-2.36).

LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The meta-analysis across all forms of study, utilising a total of 13 analyses, yielded a significant Summary Risk Estimate of 1.22 (1.04 –1.44) for cancer of the stomach. This was lower than the meta-SMR of 1.58, (1.12-2.16) and the heterogeneity of the data was not significant at the 10% level.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, cancer of the stomach had an MOR=1.2 (0.9-1.6), based on 52 deaths. For black firefighters the MOR was 1.2 but there were insufficient deaths (3) for a confidence interval to be computed.

Ma et al., 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	Twelve deaths from stomach cancer amongst the male cohort yielded an SMR=0.86 (0.52-1.42). No deaths from this cancer were recorded amongst the female cohort. A subsidiary analysis of ten deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave a very similar outcome with SMR=0.92 (0.68-2.00).
Ma et al., 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	Fourteen registered cases of stomach cancer amongst the male cohort yielded a SIR=0.50 (0.25-0.90). No cases of this cancer were recorded amongst the female cohort.

Tornling <i>et al.</i> 1994	An investigation of cancer incidence and mortality rates in Swedish firefighters. All male firefighters employed for at least one year in the City of Stockholm between 1931 and 1981 were traced. This resulted in 1,153 individuals but a further group were already deceased so the total sample size was 1,116 males. Exposure measures were also made using a 10% sample of fire reports which was developed into an exposure index for each calendar year and each fire station. Standardised mortality ratios were calculated. The analysis identified that overall mortality was lower than expected (SMR=82; 95% CI 72-91). The cancer incidence was equal to expected but increased stomach cancer was observed (SMR=192; CI 114-304) and brain cancer (SMR 496; 95% CI 135-270).	++	Twelve deaths from stomach cancer resulted in an SMR=121 (62-211). However, the incidence of stomach cancer was significantly elevated (SIR=192, 114-304). Analyses of stomach cancer incidence were also conducted by age; years of employment; latency (years since first employment); and number of fires attended. There were elevated risks amongst those employed for >30years (SIR=289, 149-505); for latencies of <30 years (SIR=481, 155-1122) and 30-40 years (SIR=606, 313-1059) (but not >40 years); and for those who attended >1,000 fires per year (SIR=264, 136-461). None of the equivalent mortality analyses yielded significant results although the SMRs did suggest similar trends.
Vena and Fiedler, 1987	A mortality study of municipal workers which all full-time employees of Buffalo USA between 1950 and 1979 for a minimum of 5 years. Individuals who had worked at least one year as a firefighter were included. At data collection this was 1,867 white male firefighters including 890 currently employed, 740 retirees, 65 who had resigned and 172 who died in service. The analysis identified that firefighters had significantly more benign neoplasms (SMR=4.17; 95% CI 1.34-9.73), malignant neoplasms including colon cancer (SMR=1.83; 95% CI 1.05-2.97), and bladder cancer (SMR=2.86; 95% CI 1.30-5.40).	++	Seven deaths from stomach cancer amongst the cohort yielded an SMR=1.19 (0.48-2.46). Cancer of the oesophagus did not feature in subsidiary analyses of firefighters with estimates of exposure. Although not analysed separately there were indications of a possible trend with years worked as a firefighter for all cancers of the digestive system (ICD 9, 150-159): 1-9 years: 0.67; 10-19 years: 0.40; 20-29 years: 0.78; 30-39 years: 1.33; 40+ years: 3.08. The final Risk Ratio was statistically significant.

3.2.6 Cancer of the Colon

Cancer of the colon amongst firefighters was reported in 16 of the primary studies and five of the review papers. Where ICD codes were reported these were either 153 (ICD 8 & 9) or C18 (ICD 10). Some authors utilised the ICDO nomenclature which followed ICD 9 chronologically and appears to reflect this for the main coding. Some papers combined cancer of the colon with that of the rectum. These have been omitted from the results below.

Figure 4 shows the main findings from each of the 13 primary studies reporting any association, where a numerical value and confidence intervals were presented. From this it can be seen that there was little consistency, with eight studies reporting a positive association and four negative (one being exactly unity). The two largest positive effects were statistically significant.

In the two studies which identified a statistically significant association two (Baris *et al.*, 2001, Vena *et al.*, 1987) examined dedicated cohorts of firefighters with 7,789 and 1,867 members respectively. A third Kang *et al.*, 2008 examined 2,125 entries in a cancer registry relating to firefighters. However, it should be noted that, in this latter study, the Odds Ratio was only increased significantly when police were used as the reference group. When the total for all the other occupations was utilised then the odds ratio, although still greater than 1.0 (1.15, 0.93-1.43) was no longer statistically significant.

There were no consistent differences between these three studies and the remainder in terms of period of follow-up or methodological factors to promote these over the others which identified smaller, non-significant effects.

Similarly, examining the two studies which identified a relatively large (but not significant) protective effect (Aronson *et al.*, 1994, Bates *et al.*, 2001) there was no apparent reason to differentiate these papers to accord them more or less credence.

Although reported together with cancer of the rectum, it should be noted that Donnan (1996) reported a Standardised Registration Ratio of 0.56 (0.32-0.93), indicating a lower than expected incidence within the five Brigades from which the cohort was formed.

Of the 13 papers, nine presented an estimate of person-years of follow-up (or equivalent). These totalled 1,508,428 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al.* 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

The two studies by Ma and co-workers (Ma *et al.*, 2005, Ma *et al.*, 2006), on essentially the same cohort of Florida firefighters, had sufficient data to analyse female firefighters. This is exceptional as other studies generally excluded fire females on the basis that there were too few for meaningful analysis. Although the number of females in their cohort was proportionately small (2,017 compared to 34,796 males) the effective sample size made it larger than a number of other studies reported here. In the mortality study Ma *et al.*, 2005, one death from colon cancer amongst the cohort resulted in an Odds Ratio of 2.27 (0.03-12.7) whilst the morbidity study Ma *et al.*, 2006 identified two registered cases of colon cancer, yielding an identical Odds Ratio of 2.27 (0.26-3.21). These two studies encompassed 17,548 and 18,843 person-years respectively.

Clearly, with relatively low incidence and mortality rates, it is difficult to ignore the possibility that these results are anything other than chance (hence the very wide confidence intervals). However, these Odds Ratios are greater than many of the studies of male firefighters, often with a larger cohort, and with an increasing number of females entering the Fire Service in the UK, this finding supports the suggestion of a need for careful monitoring of the health of these females in future years.

Five review papers identified cancer of the colon as a specific cancer of interest although one of these (Golden *et al.*, 1995) combines this category with that of rectal cancer, making cross-comparisons difficult.

The next of these reviews (Howe and Burch, 1990) identified six papers in relation to cancer of the colon, three cohort studies included in the present review and three proportionate mortality studies in which the data were derived from general population studies. The authors calculate cumulative SMRs (cohort studies) and PMRs yielding remarkably similar values of 1.12 (0.77-1.57) for the former and 1.06 (0.81-1.36) for the latter. Having considered the limitations of some of the studies, including the absence of data on possible confounders, the authors concluded that consideration of causality was not warranted.

(Guidotti, 1995) presented what was described as a critique of the available literature. Unlike formally instituted reviews, the basis for the identification of the papers included is not given. The author presents risk estimates from 16 papers, most of which are included in the present review. However, the selection of values to report is a little confused. For example, the paper by (Eliopoulos *et al.*, 1984) is included although the value cited is for intestinal cancer. ICD 8, which Eliopoulos and co-workers reportedly used, has two codes: 152 for the small intestine and 153 for the large intestine (which becomes the code for the colon in the ICD 9 classification). It is not clear therefore whether this paper encompasses one or the other (or both) of these categories. Setting this aside, the 16 estimates presented range from 60-183, only one of which is statistically significant. Based on this, the author classifies cancer of the colon as having an approximate magnitude of association of 150.

The next review (Youakim, 2006) included both mortality and morbidity studies from New Zealand and Sweden (both included in the present review) as well as data from eight mortality studies (all in the present review) and two others (again in this review) from the USA and Canada. Based on the mortality studies alone, the author calculated a summed Risk Ratio of 1.07 (0.95-1.18) for all studies combined, rising slightly to 1.14 (0.97-1.18) for cohort studies only. For morbidity studies, values of 1.06 (0.34-1.32) for all studies and 0.91 (0.64-1.25) for cohort studies were derived. Once again therefore the conclusion from the overall statistics was that there was no evidence for significantly elevated mortality risk for colon cancer.

The author reported a sub-cohort analysis of duration of employment. Most of the sub cohorts fail to show any trend with increasing duration, up to and including 30 years. However, a final sub-cohort (≥ 40 years) showed an SMR of 4.71 (2.03-9.27). This result should be interpreted with caution as, unlike earlier sub-cohorts which were based on three to four studies, this final set was based on one paper Vena *et al.*, 1987. Previous authors ((Howe *et al.*, 1990) concluded that the data from this particular study constituted a probable outlier, choosing not to attach too much significance to it. The absence of any apparent trend in earlier decades of service would seem to support this view.

Finally, LeMasters *et al.*, 2006 reported on a review and meta-analysis of cancer risk amongst firefighters, including cancer of the colon. They included ten papers which

included a mortality study SMR, four quoting PMRs, two with Relative Risks and four reporting incidences (SIRs) although one of these (Giles *et al.*, 1993) included both colon cancer and rectal cancer. Two further papers were cited which presented mortality or incidence (one of each) from case-control Odds Ratio studies. Again, one paper cited was that on the police/firefighter cohort (Demers, *et al.*, 1992b),

Summarising their findings, the authors presented a summary Risk Estimate of 1.21 (1.03–1.41) which they classified as a possible risk. However, the authors do indicate that there was considerable variation between studies, with a heterogeneity which was significant at the 10% level. This was apparent from examining the calculated risks from each type of study examined separately. Thus, SMRs from mortality studies yielded a meta-Relative Risk of 1.34 (1.01–1.79); PMR studies gave a meta-Relative Risk of 1.25 (0.90–1.74); Relative Risk studies resulted in a meta-Relative Risk of 0.91 (0.60–1.36); and SIRs from incidence studies gave a meta-Relative Risk of 0.9 (0.69–1.17). The two case-control/mortality Odds Ratio studies yielded Odds Ratios of 1.00 (0.90–1.20) (mortality) and 1.04 (0.59–1.82) (morbidity) although this was when using police, rather than general state employees as the comparison group. Clearly, pooling the data from the various studies has improved the sensitivity of the analysis and resulted in a significant outcome. Although there might be some duplication across different cohorts this does not seem to be significant.

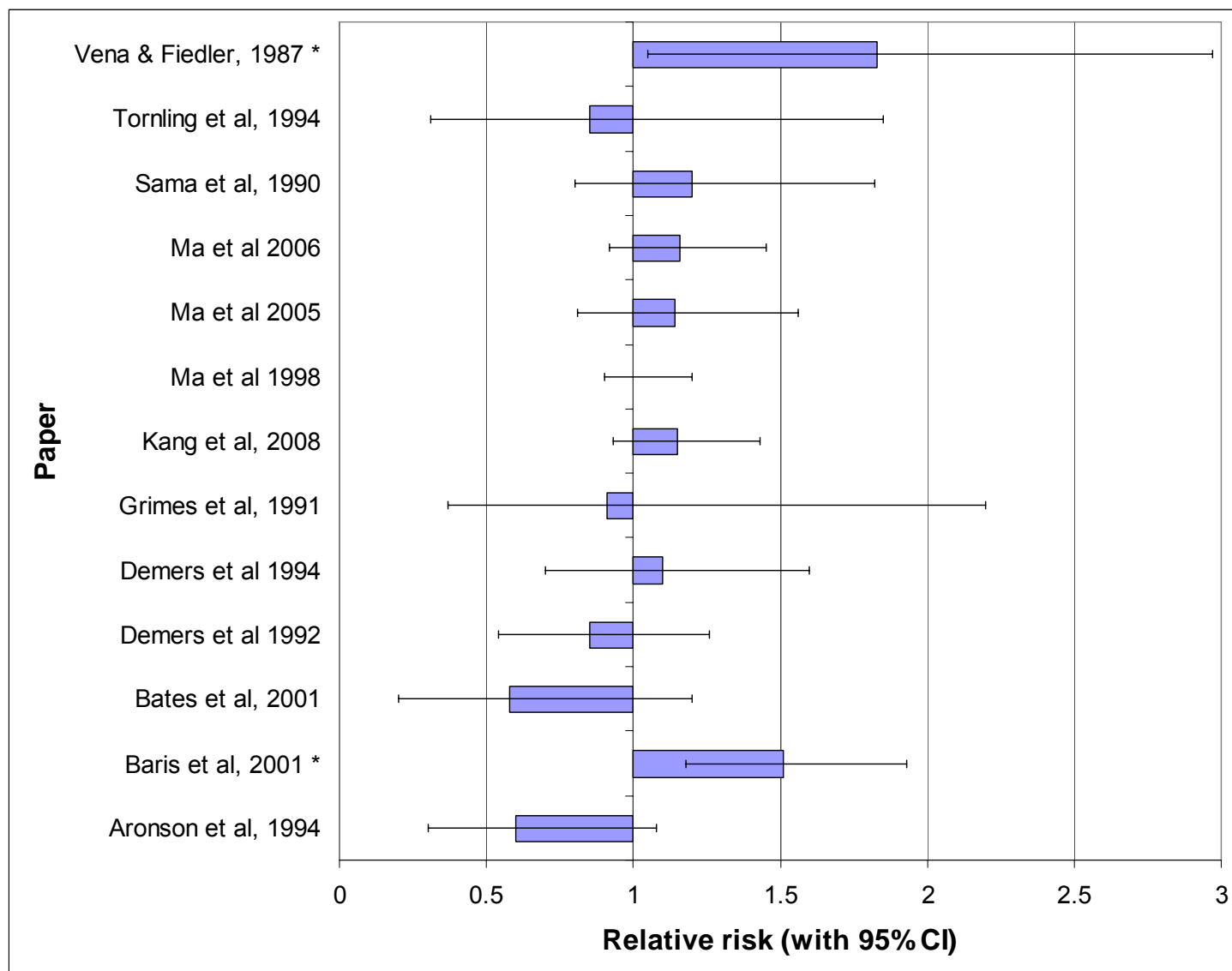
The review does not include a number of papers, published more recently, which might have some bearing on the results quoted for the various meta-analyses. Thus, there is no mention of either the mortality study Ma *et al.*, 2005 or the subsequent morbidity study Ma *et al.*, 2006 of firefighters from Florida, both of which showed a small but non-significant positive association between colon cancer and being a firefighter. Similarly, the paper by Kang *et al.*, 2008 of cancer incidence amongst firefighters from Massachusetts, which also found a small but non-significant positive association, is also not included.

In conclusion, although there is a lack of general consistency of findings between different studies, the collective evidence would appear to suggest a modest positive association between colon cancer and being a firefighter. The estimated size of the effect is difficult to determine but, bearing in mind studies published since its calculation, the summed Risk Estimate of LeMasters *et al.* (2006) of 1.21 (1.03–1.41) would appear to give a reasonable guide.

As the range of estimates fall well short of the criterion of 2.0, issues such as the plausibility of the association being causal will not be studied further. However, there might be some value in the future of exploring the various studies in greater depth in order to understand better the sources of variation between studies.

As stated above, Donnan (1996) reported an SRR of 0.56 for colon cancer and rectal cancer combined amongst a cohort of UK firefighters, slightly lower than any published estimate and, to the extent that colonic and rectal cancers can be considered to be co-related, clearly suggesting an absence of any positive association in a UK-based cohort.

Table 4 summarises the evidence relating to firefighting and cancer of the colon.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 4: Comparisons of relative risks (with 95% confidence intervals) for colon cancer, derived from published studies

Table 4. Evidence relating to Fire Fighting and Colon Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were 11 deaths attributed to cancer of the colon (ICD 9, 153) in the cohort, yielding a non-significant SMR of 60 (30-108). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of these deaths.

Baris <i>et al.</i> , 2001	<p>Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; 1.11-2.63); colon cancer (SMR=1.94; 1.38-2.73); multiple myeloma (SMR=2.54; 1.15-5.67); benign neoplasms (SMR=2.95; 1.41-6.19); & IHD (SMR=1.14; 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations.</p>	++	<p>Sixty four deaths attributed to cancer of the colon (ICD 9, 153) yielding a significant SMR of 1.51 (1.18-1.93). In the analysis of duration of employment as a surrogate for exposure there was no linear trend across the three categories: (≤ 9 years, SMR=1.78 (1.12-2.82); 10-19 years, SMR=1.11., (0.68-1.81); ≥ 20 years, SMR=1.68; 1.17-2.40). As an alternative measure of exposure, those who were in engine companies were more likely to die from colon cancer which was seen as consistent with the suggestion that members of this sub-cohort would have been likely to have received greater exposure to possibly toxic substances than others. (engine company: SMR=1.94, (1.38-2.73); ladder company: SMR=0.59 (0.15-2.35); both ladder and engine companies: SMR=1.19, (0.81-1.77)). There were suggestions that those recruited more recently were likely to show greater mortality than those recruited earlier. (pre-1935: SMR=1.00 (0.61-1.63); 1935-1944: SMR=2.00, (1.38-1.90); post 1944: SMR=1.60, (1.03-2.49)).</p>
Bates <i>et al.</i> , 2001	<p>This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).</p>	+	<p>In the whole-period analysis (1977-1996) cancer of the colon had an SIR=0.60 (0.2-1.2) based upon seven cancers. Over the shorter period for which there was considered to be more complete data (1990-1996), there were four such cancers yielding a very similar SIR=0.58 (0.2-1.5).</p> <p>Analysis of the data by years of paid service only, demonstrated an apparent trend for an increased incidence although none of the SIRs were statistically significant: 0-10 years: SIR=0.41, 0.0-2.3; 11-20 years: SIR=0.46, 0.0-2.6; ≥ 20 years: SIR=1.37, 0.4-3.2. A similar but smaller trend was observed amongst paid and volunteer firefighters combined. Mortality over the whole period had an elevated but non-significant SMR=1.19 (0.4-2.6).</p>

Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Cancer of the colon had an SMR=0.85 (0.54-1.26) based on 24 deaths. An analysis by duration of exposed employment showed no particular trend: <10years: SMR=1.40 (0.4-3.6); 10-19 years: SMR=0.54 (0.1-2.0); 20-29 years: SMR=0.62 (0.3-1.2); > 30 years: SMR=1.21 (0.6-2.3). A similar analysis by years since first employment also showed no particular pattern: <20 years: SIR=0.51 (0.1-2.9); 20-29 years: 0.66 (0.1-1.9); SIR=30+ years: SIR=0.91 (0.6-1.4). Finally, the authors analysed the data by age at risk, which again showed no trend for cancer of the colon: 18-39 years old: SMR=1.38 (0.1-8.2); 40-64 years old: SMR=0.78 (0.4-1.4); >65 years old: SMR=0.86 (0.5-1.5).
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. Comparison group was 1878 police officers. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Cancer of the colon had an SIR=1.1 (0.7-1.6) based on 23 incident cases. An analysis by duration of exposed employment showed some signs of an increasing trend, although none of the SMRs were significant: <10 years: 0.8 (0.1-2.9); 10-19 years: 0.7 (0.1-2.6); 20-29 years: 1.1 (0.6-1.9); 30+ years: 1.5 (0.4-3.9). A similar analysis by years since first employment showed no particular pattern: <20 years: SIR=0.0 (0.0-5.7); 20-29 years: SIR=1.2 (0.3-3.5); 30+ years: SIR=1.1 (0.7-1.7).
Grimes <i>et al.</i> 1991	A twenty year Proportionate Mortality study was conducted with all male firefighters in the City of Honolulu from 1969-1988 who had at least one year of service. This covered 205 deaths. Significant increases in risk of death were found for brain cancer (ICD 9, 191-192) (PMR=3.78, 1.22-11.71); prostate cancer (ICD 9 185) (PMR=2.61, 1.38-4.97); and cirrhosis of the liver (ICD 9 571) (PMR=2.3, 1.21-4.37). It was suggested that the latter could, at least in part, be attributed to an excess of alcohol consumption in this group. A significant decrease in mortality was observed for respiratory diseases (ICD 9 460-519) (PMR=0.37, 0.17-0.81).	+	The PMR for cancer of the colon (ICD 9, 153) was 0.91 (0.37-2.20) based upon 5 deaths. A subsidiary analysis for firefighters of Caucasian or Hawaiian extraction yielded values of 0.71 (0.10-5.02) and no PMR based upon one and no deaths respectively.

Guidotti, 1995	Reviews studies of mortality in firefighters. Appears to have included all the main studies identified elsewhere but fails to describe process of identifying and selecting papers. Text summarises major findings and table presents SMR (or PMR) values and confidence intervals. Overall summary table presented as the approximate magnitude of any associations as 100, 150 or 200, presumably signifying relative risk (base 100). These are presumably based upon an interpretation of the accumulated evidence but the method of their derivation is not given. Basis of selection for chosen outcomes to address is not given, described as "specific outcomes of interest". Not all outcomes referred to in text are covered in final table. Thus, the text refers to genitourinary cancers (excluding bladder cancer) as "relatively uncommon cancers...and the risk appears to be high, close to or in excess of a doubled relative risk." Only bladder cancer data abstracted in study summaries and overall summary of associations.	-	The author presented 16 estimates from the literature ranging from 60-183, only one of which was statistically significant. Based on this, the author classified cancer of the colon as having an approximate magnitude of association of 150.
Howe and Burch, 1990	Review paper from 1990. Looked at 'all cancers' and "those specific cancers which individual studies have reported to show an association with the occupation of fire fighter". Lung, colon, brain, malignant myeloma and multiple myeloma were chosen. Studies with any demonstrable major bias were excluded (not listed). Pooled estimate showed sig all cause reduced risk (0.92, 0.85-0.98) in SMR but increased (1.09, 1.01-1.17) PMR which authors dismiss as artefact of healthy worker effect. For lung cancer the pooled SMR/PMR values were 0.92/1.08, neither of which were sig. Pooling colon cancer studies again yielded non-sig effects (SMR, 1.12, PMR, 1.06). For brain tumours the pooled SMR of 1.43 and PMR of 1.45 narrowly missed sig (CI, 0.93-2.12 & 0.95-2.12 respectively). Authors point out that the main study unsupportive of an effect related primarily to pre-WW2 exposures when, it is hypothesised, exposures to carcinogens would have been less. No dose-response relationship has been seen but causation is seen as biologically plausible. Sig increased risk of malignant melanoma based on pooled estimate of 1.73 from 5 studies. Exposure-response relationship also seen. However, authors regard causal connection as implausible with high risk of confounding. For multiple myeloma, increased pooled risk of 1.51 is not sig. This value is distorted by high value (10.00) in 1 study.	+	The authors identified six papers in relation to cancer of the colon, three cohort studies and three proportionate mortality studies in which the data were derived from general population studies. They calculated cumulative SMRs (cohort studies) and PMRs yielding remarkably similar values of 1.12 (0.77-1.57) for the former and 1.06 (0.81-1.36) for the latter.

Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Colon cancer yielded an SMOR=1.15 (0.93-1.43) based on 200 registrations. There were indications of an increasing trend in the age-stratified data: 18-54: SMOR=1.05 (0.55-1.99); 55-74: SMOR=1.24 (0.85-1.81); 75+: SMOR=1.73 (1.06-2.84).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The meta-analysis across all forms of study, utilising a total of 25 analyses, yielded a significant Summary Risk Estimate of 1.21 (1.03 –1.41) for cancer of the colon. This was slightly lower than the meta-SMR and PMR of 1.31, (1.08-1.59) and the heterogeneity of the data was significant at the 10% level.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, cancer of the colon had an MOR=1.0 (0.9-1.2), based on 149 deaths. For black firefighters the MOR was 2.1 (1.1-4.0) based on 9 deaths.

Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk of atherosclerotic heart disease (3.85; 1.66-7.58)	++	38 deaths from cancer of the colon amongst the male cohort yielded an SMR=1.14 (0.81-1.56). One death from this cancer was recorded amongst the female cohort yielding an SMR=2.27 (0.03-12.7). A subsidiary analysis of 33 deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave a very similar outcome with SMR=1.22 (0.84-1.72).
Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified (94.5% male, 5.5% female). The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	78 registered cases of cancer of the colon amongst the male cohort yielded a SIR=1.16 (0.92-1.45). Two cases of this cancer were recorded amongst the female cohort, yielding an SIR=2.27 (0.26-8.21). No exposure-related analysis was reported.
Sama <i>et al.</i> , 1990	A study using cancer registry data from Massachusetts in the USA. Samples included 315 male cancer cases between 1982 and 1986; 392 male white police officers and 29,277 State cases. The analysis included SMORS and it was identified that there was an elevated risk of melanoma (SMOR=292; 95% CI 170-503), bladder cancer (SMOR 159; 95% CI 107-414) for firefighters compared to State residents. In comparison with police officers, there was an increase risk in bladder cancer (SMOR=211; 95% CI 107-414) and non-Hodgkin's Lymphoma (SMOR=32; 95% CI 119-898). A number of difficulties with the study were identified by the researchers including the potential for underreporting of cancers.	++	33 registered cases of cancer of the colon amongst the cohort yielded a SMOR=120 (80-182). No exposure-related analysis was presented in respect of this form of cancer.

Tornling <i>et al.</i> 1994	An investigation of cancer incidence and mortality rates in Swedish firefighters. All male firefighters employed for at least one year in the City of Stockholm between 1931 and 1981 were traced. This resulted in 1,153 individuals but a further group were already deceased so the total sample size was 1,116 males. Exposure measures were also made using a 10% sample of fire reports which was developed into an exposure index for each calendar year and each fire station. Standardised mortality ratios were calculated. The analysis identified that overall mortality was lower than expected (SMR=82; 95% CI 72-91). The cancer incidence was equal to expected but increased stomach cancer was observed (SMR=192; CI 114-304) and brain cancer (SMR 496; 95% CI 135-270).	++	Six deaths from cancer of the colon resulted in an SMR=85 (31-185). The incidence of stomach cancer yielded a similar result: SIR=90 (39-177). No exposure-related analyses of cancer of the colon were reported.
Vena and Fiedler, 1987	A mortality study of municipal workers which all full-time employees of Buffalo USA between 1950 and 1979 for a minimum of 5 years. Individuals who had worked at least one year as a firefighter were included. At data collection this was 1,867 white male firefighters including 890 currently employed, 740 retirees, 65 who had resigned and 172 who died in service. The analysis identified that firefighters had significantly more benign neoplasms (SMR=4.17; 95% CI 1.34-9.73), malignant neoplasms including colon cancer (SMR=1.83; 95% CI 1.05-2.97), and bladder cancer (SMR=2.86; 95% CI 1.30-5.40).	++	16 deaths from cancer of the colon amongst the cohort yielded an SMR=1.83 (1.05-2.97) which was statistically significant. There were indications of a possible trend with years worked as a firefighter for cancer of the colon: 1-9 years: no value; 10-19 years: 1.25; 20-29 years: 0.87; 30-39 years: 1.43; 40+ years: 4.71. The final Risk Ratio was statistically significant.
Youakim, 2006	An analysis of 16 studies to identify risk of cancer among firefighters. The study identified an increase in risk of kidney cancer (sumRR 1.25; 95% CI 1.02-1.43) and non-Hodgkin's Lymphoma (sumRR 1.4; 95% CI 1.20-1.60). Further analysis using a sub-cohort of studies was also made based on duration of employment, with 30 years or more as a firefighter having an increased risk for colon cancer (sumRR 1.51; 95% CI 1.05-2.11), kidney cancer (sumRR 36.12; 95% CI 1.70-16.00), brain cancer (sumRR 2.53; 95% CI 1.27-7.07) and leukaemia (sumRR 2.87; 95% CI 1.43-5.14). After 40 years employment risks for mortality from colon cancer were (sumRR 4.71; 95% CI 2.03-9.27), kidney cancer (sumRR 36.2; 95% CI 4.03-120.42) and bladder cancer (sumRR 5.7; 95% CI 1.56-14.33).	++	The summed mortality Risk Ratio calculated for cancer of the colon was 1.07 (0.95-1.18) for all studies and 1.13 (0.97-1.29) for cohort studies only. This was based upon 10 studies although one of these reported cancers of the intestine (excluding the rectum) and not just the colon. For morbidity the calculated summed Risk Ratio was 1.06 (0.84-1.32) for all studies and 0.91 (0.64-1.25) for cohort studies only. Exposure for more than 30 years as a firefighter resulted in an increased risk for mortality from colon cancer (sumRR 1.51; 95% CI 1.05-2.11). For more than 40 years of employment the risk for mortality from colon cancer was sumRR=4.71 (2.03-9.27). However, this latter figure was derived from data drawn from only one study whilst earlier values were based on at least three. There was a trend for increasing morbidity with years of exposure, rising from SIR=0.61 for less than 10 years to SIR=1.50 for more than 30 years, although none of the values were statistically significant.

3.2.7 Rectal Cancer

Fourteen papers were identified which presented a risk estimate (and confidence interval) for rectal cancer (excluding those who combined this with cancer of the colon). This included the two largely parallel morbidity and mortality cohorts of Ma and co-workers (2005 and 2006) and Demers and co-workers (1992a and 1994). Three reviews covering this form of cancer were also identified. The results from these papers are given in Figure 5.

The findings show some interesting contrasts with cancer of the colon, to which it might be expected to be related and with which it is sometimes merged. Thus, a number of papers show a reversal of the trend they reported for colon cancer, of which the most marked are the switch from a significant positive association to a (marginally) negative association by Baris *et al* (2001) and the marked reversals reported by Aronson *et al* (1994) and Tornling *et al* (1994).

Amongst the findings for rectal cancer, only that by Burnett *et al* (1994) achieves statistical significance (PMR=148, 105-205). However, particularly when the overlapping papers are taken into account, the general impression is for a small positive association. In two papers the elevated risk exceeds 2.0 (Vena and Fiedler, 1987; Tornling *et al*, 1994) although this is not a consistent finding.

Again, the risk estimate reported by Donnan (1996), combining rectal cancer with cancer of the colon should be noted here, with a decreased risk of rectal cancer amongst the cohort of UK firefighters (compared to the average for England and Wales) which was statistically significant (0.56, 0.32-0.93).

Of the 14 papers, nine presented an estimate of person-years of follow-up (or equivalent). These totalled 1,508,428 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

Golden *et al* (1992) review ten papers, including one showing a significant positive association which is not included in the present review. However, this is cited as an abstract and does not appear to have been published as a full, peer-review article. The authors comment on the predominance of a positive association which they consider to be a consistent finding.

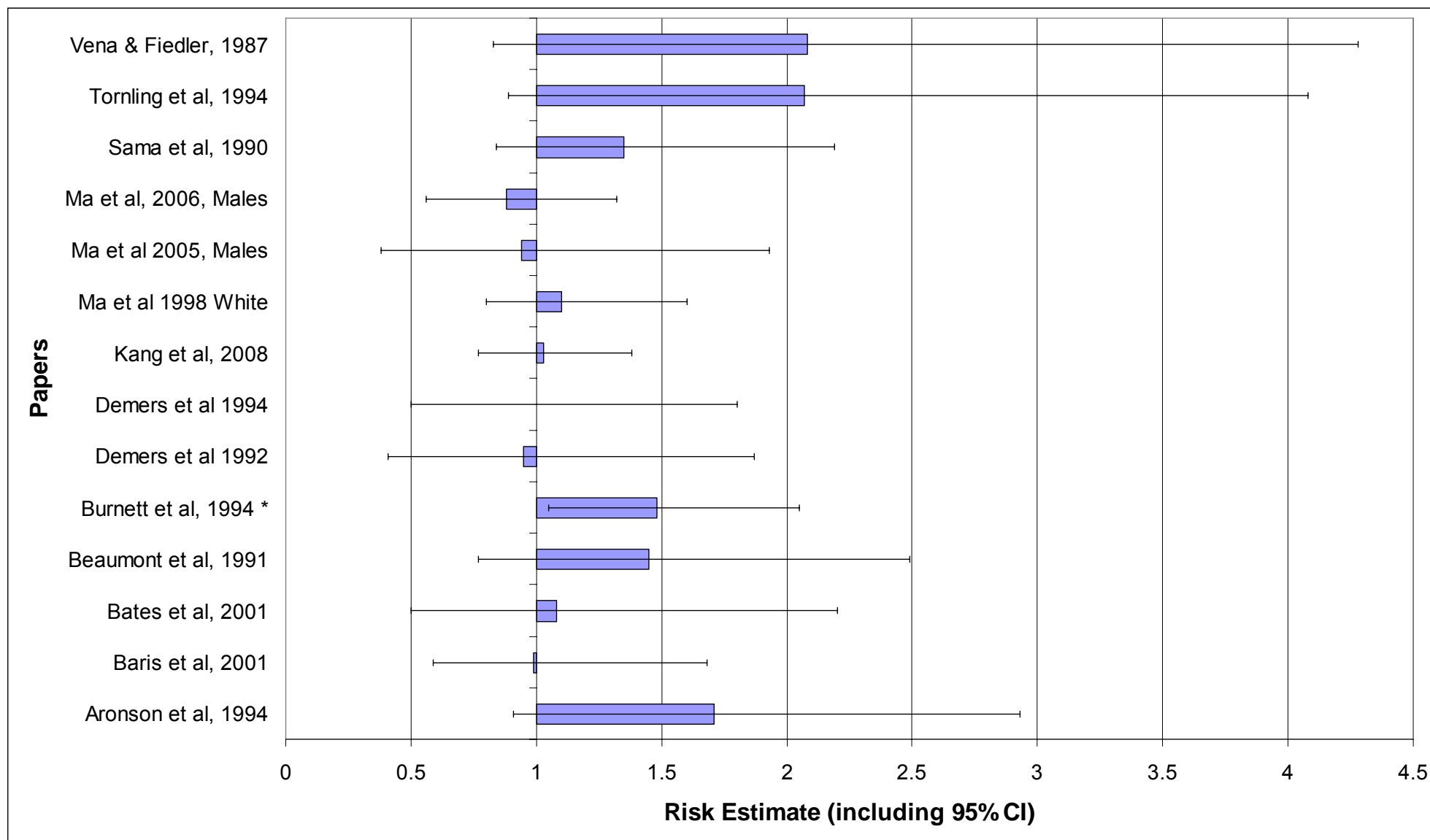
Guidotti (1995) quotes 13 risk estimates for rectal cancer (plus one other rectal and colonic combined). Of the 13, five show negative associations. The author concludes that there is a “likely cause” association, with an approximate magnitude of risk estimate of 150? [sic]. Clearly, this does not include the more recent papers of Ma and co-workers; Kang *et al*; Bates *et al*; or Baris *et al*, all of which show lower estimates.

LeMasters *et al* (2006) derive a summary Risk Estimate of 1.29 (1.10-1.51), based on 13 analyses from twelve papers including Demers, *et al* (1992b) which reported a firefighter/police incidence (SIR) of 0.95 (0.55-1.52) compared to 1.0 (0.5-1.8) in the near equivalent firefighter cohort of Demers *et al*, (1994). As usual, this excluded the Ma and co-workers Florida cohort (2005 and 2006) and the study by Kang *et al* (2008). Inclusion of these would clearly reduce the risk estimate somewhat, although it would probably remain positive. Given that both the mortality and morbidity studies of Ma and colleagues (2005 and 2006) identified a negative association there must be some doubt whether any adjusted summary Risk Estimate would remain statistically significant. What is clear however is that although, as with colon cancer,

there would appear to be a reasonably consistent positive association between rectal cancer and being a firefighter, such an association is undoubtedly modest (<1.29) and clearly below 2.0.

Finally, Ma *et al* (2006) reported a marked positive association with rectal cancer incidence and female firefighters. However, this was based on only one incident case, which explains the very wide confidence interval (5.26, 0.07-29.30). However, with the two incidence cases of colonic cancer this again illustrates a need for future vigilance with this sub-cohort.

Table 5 presents the data relating to firefighting and rectal cancer.



KEY: * indicates risk statistically significantly different from 1.0 (p=0.05)

Figure 5: Comparisons of relative risks (with 95% confidence intervals) for rectal cancer, derived from published studies

Table 5. Evidence relating to Fire Fighting and Rectal Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were 13 deaths attributed to cancer of the rectum (ICD 9, 154) in the cohort, yielding a non-significant SMR of 171 (91-293). Further analysis by years since first employment, as a surrogate for exposure showed a non-significant trend for an increased mortality risk: <20 years: 135 (3-753); 20-29 years: 146 (18-527); >=30 years: 182 (87-336). An analysis by years of employment did not show a similar trend: <15 years: 0 (0-467); 15-29 years: 235 (76-548); >=30 years: 174 (75-343). Finally, an analysis of deaths by age showed a higher but non-significant risk amongst the older sub-cohort: <60 years: SMR=139 (38-356); >=60 years 191 (87-363).

Baris <i>et al.</i> , 2001	<p>Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations.</p>	++	<p>14 deaths attributed to cancer of the rectum (ICD 9, 154) yielding a non-significant SMR of 0.99 (0.59-1.68). In the analysis of duration of employment as a surrogate for exposure there was no linear trend across the three categories: (≤ 9 years, SMR=0.86 (0.28-2.66); 10-19 years, SMR=1.16, (0.52-2.58); ≥ 20 years, SMR=0.92; 0.38-2.22). As an alternative measure of exposure, those who were in engine companies were no more likely to die from colon cancer than others who worked in both engine and ladder companies. (engine company: SMR=1.04, (0.47-2.31); ladder company: no SMR; both ladder and engine companies: SMR=1.04, (0.50-2.18)). There was no meaningful trend of mortality related to year of employment: (pre-1935: SMR=1.05 (0.50-2.21); 1935-1944: SMR=0.73, (0.23-2.26); post 1944: SMR=1.20, (0.45-3.20)).</p>
Bates <i>et al.</i> , 2001	<p>This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).</p>	+	<p>In the whole-period analysis (1977-1996) cancer of the rectum had an SIR=1.15 (0.5-2.2) based upon nine cancers. Over the shorter period for which there was considered to be more complete data (1990-1996), there were five such cancers yielding a very similar SIR=1.08 (0.3-2.5).</p> <p>Analysis of the data by years of paid service only, demonstrated an apparent trend for an increased incidence although none of the SIRs were statistically significant: 0-10 years: SIR=1.22, 0.1-4.4; 11-20 years: SIR=1.38, 0.2-5.0; >20 years: SIR=1.61, 0.4-4.1. A similar but smaller trend was observed amongst paid and volunteer firefighters combined. Mortality over the whole period had an elevated but non-significant SMR=1.21 (0.3-3.1).</p>

Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for cancer of the rectum was elevated, but not significantly (1.45, 0.77-2.49), based on 13 deaths. Exposure-related data for this cancer did not include confidence intervals and displayed no particular trend. Time since first employment: 3-19 years: RR=2.64; 20-29 years: RR=1.05; 30-39 years: RR=1.04; 40+ years: RR=1.77. Length of employment: 3-9 years: RR=0.00; 10-19 years: RR=2.19; 20-29 years: RR=1.45; 30+ years: RR=1.42.
Burnett <i>et al.</i> , 1994	Assessment of mortality rates for firefighters using information from 27 USA states between 1984-1990. In total 5,744 deaths in white male firefighters were reviewed and analysis was based on proportionate mortality ratios comparing deaths from specific causes as compared to all causes in firefighters. The study identified there was increased levels of malignant neoplasms (PMR=110; 106-114), rectal cancer (PMR=148; 105-205), skin cancer (PMR=163; 115-223), kidney cancer (PMR=144; 108-189), lymphatic and haematopoietic cancers (PMR=130 111-151) and multiple myeloma (PMR=148; 102-207).	++	The study identified an increased total risk of rectal cancer with a PMR=148 (105-205) which was higher for those under 65 years of age, when the PMR=186 (110-294). No further analysis was reported.
Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 1.1-3.6) and leukaemia (SMR=2.6; 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Rectal cancer had an SMR=0.95 (0.41-1.87) based on 8 deaths. This cancer did not feature in any of the analyses for surrogates of exposure.

Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. Comparison group was 1878 police officers. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Rectal cancer had an SIR=1.4 (0.60-2.7) based on 12 incident cases. An analysis by duration of exposed employment showed no particular pattern: <10 years: 1.4 (0.2-4.9); 10-19 years: 1.9 (0.4-5.4); 20-29 years: 0.7 (0.2-1.6); 30+ years: 1.3 (0.5-2.8). A similar analysis by years since first employment also showed no particular pattern: <20 years: SIR=0.0 (0.0-8.8); 20-29 years: 2.2 (0.6-5.7); SIR=30+ years: SIR=0.8 (0.4-1.7).
Golden <i>et al</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain,; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	
Guidotti, 1995	Reviews studies of mortality in firefighters. Appears to have included all the main studies identified elsewhere but fails to describe process of identifying and selecting papers. Text summarises major findings and table presents SMR (or PMR) values and confidence intervals. Overall summary table presented as the approximate magnitude of any associations as 100, 150 or 200, presumably signifying relative risk (base 100). These are presumably based upon an interpretation of the accumulated evidence but the method of their derivation is not given. Basis of selection for chosen outcomes to address is not given, described as "specific outcomes of interest". Not all outcomes referred to in text are covered in final table. Thus, the text refers to genitourinary cancers (excluding bladder cancer) as "relatively uncommon cancers...and the risk appears to be high, close to or in excess of a doubled relative risk." Only bladder cancer data abstracted in study summaries and overall summary of associations.	-	Cites one paper in stating that firefighters "have an increased risk for colon cancer, a risk shared with cancer of the rectum". Despite this lack of supporting evidence the summary table suggests an approximate magnitude of risk of 150 for rectal cancer although it is qualified as "150?".

Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Cancer of the rectum yielded an SMOR=1.03 (0.77-1.38) based on 67 registrations. No trend was apparent in the age-stratified data: 18-54: SMOR=0.97 (0.39-2.46); 55-74: SMOR=0.94 (0.57-1.57); 75+: SMOR=0.70 (0.31-1.56).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The meta-analysis across all forms of study, utilising a total of 13 analyses, yielded a significant Summary Risk Estimate of 1.29 (1.10-1.51) for cancer of the rectum. This was slightly lower than the meta-SMR and PMR of 1.39, (1.12-1.70) and the heterogeneity of the data was not significant at the 10% level.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, cancer of the rectum had an MOR=1.1 (0.8-1.6), based on 27 deaths. For black firefighters there were no recorded deaths from rectal cancer.

Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	Seven deaths from rectal cancer amongst the male cohort yielded an SMR=0.94 (0.38-1.93). No deaths from this cancer were recorded amongst the female cohort. A subsidiary analysis of six deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave aslightly higher outcome with SMR=1.04 (0.38-2.26).
Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	23 registered cases of rectal cancer amongst the male cohort yielded a SIR=1.16 (0.92-1.45). One case of this cancer amongst the female cohort yielded an SIR=5.26 (0.07-29.30).
Sama <i>et al.</i> , 1990	A study using cancer registry data from Massachusetts in the USA. Samples included 315 male cancer cases between 1982 and 1986; 392 male white police officers and 29,277 State cases. The analysis included SMORS and it was identified that there was an elevated risk of melanoma (SMOR=292; 95% CI 170-503), bladder cancer (SMOR 159; 95% CI 107-414) for firefighters compared to State residents. In comparison with police officers, there was an increase risk in bladder cancer (SMOR=211; 95% CI 107-414) and non-Hodgkin's Lymphoma (SMOR=32; 95% CI 119-898). A number of difficulties with the study were identified by the researchers including the potential for underreporting of cancers.	++	22 registered cases of rectal cancer yielded an SMOR=135 (84-219). No further analysis of this form of cancer was reported.

Tornling <i>et al.</i> 1994	An investigation of cancer incidence and mortality rates in Swedish firefighters. All male firefighters employed for at least one year in the City of Stockholm between 1931 and 1981 were traced. This resulted in 1,153 individuals but a further group were already deceased so the total sample size was 1,116 males. Exposure measures were also made using a 10% sample of fire reports which was developed into an exposure index for each calendar year and each fire station. Standardised mortality ratios were calculated. The analysis identified that overall mortality was lower than expected (SMR=82; 95% CI 72-91). The cancer incidence was equal to expected but increased stomach cancer was observed (SMR=192; CI 114-304) and brain cancer (SMR 496; 95% CI 135-270).	++	8 deaths from rectal cancer resulted in an SMR=207 (89-408). The incidence of rectal cancer was slightly lower with an SIR=170, 81-312. No further analyses of rectal cancer incidence were reported.
Vena and Fiedler, 1987	A mortality study of municipal workers which all full-time employees of Buffalo USA between 1950 and 1979 for a minimum of 5 years. Individuals who had worked at least one year as a firefighter were included. At data collection this was 1,867 white male firefighters including 890 currently employed, 740 retirees, 65 who had resigned and 172 who died in service. The analysis identified that firefighters had significantly more benign neoplasms (SMR=4.17; 95% CI 1.34-9.73), malignant neoplasms including colon cancer (SMR=1.83; 95% CI 1.05-2.97), and bladder cancer (SMR=2.86; 95% CI 1.30-5.40).	++	Seven deaths from rectal cancer amongst the cohort yielded an SMR=2.08 (0.83-4.28). Cancer of the rectum did not feature in subsidiary analyses of firefighters with estimates of exposure. However, as reported previously, there were indications of a possible trend with years worked as a firefighter for all cancers of the digestive system (ICD 9, 150-159): 1-9 years: 0.67; 10-19 years: 0.40; 20-29 years: 0.78; 30-39 years: 1.33; 40+ years: 3.08. The final Risk Ratio was statistically significant.

3.2.8 Pancreatic Cancer

Sixteen papers were identified which presented risk estimates for pancreatic cancer, including the overlapping morbidity and mortality studies of common cohorts by Ma *et al* (2005 and 2006) and Demers *et al* (1992a and 1994). Figure 6 shows the risk estimates and confidence intervals from these papers. Two papers (Ma *et al*, 1998 and Ma *et al*, 2005), presenting mortality studies of two different cohorts, produced conflicting statistically significant results; with the former paper identifying a positive association between pancreatic cancer and the occupation of firefighter in records from 24 states (MOR=1.2: 1.0-1.5); and the latter a negative association amongst Florida firefighters (not in the 24 states), (SMR=0.57, 0.29-0.99). Apart from these two (and the parallel morbidity study of Florida firefighters by Ma and colleagues, 2006), the paper by Vena and Fiedler (1897) reported a sizable negative association (Odds Ratio=0.38; 0.04-1.36) although, as this was derived from only two deaths, the confidence interval is understandably large and the findings non-significant.

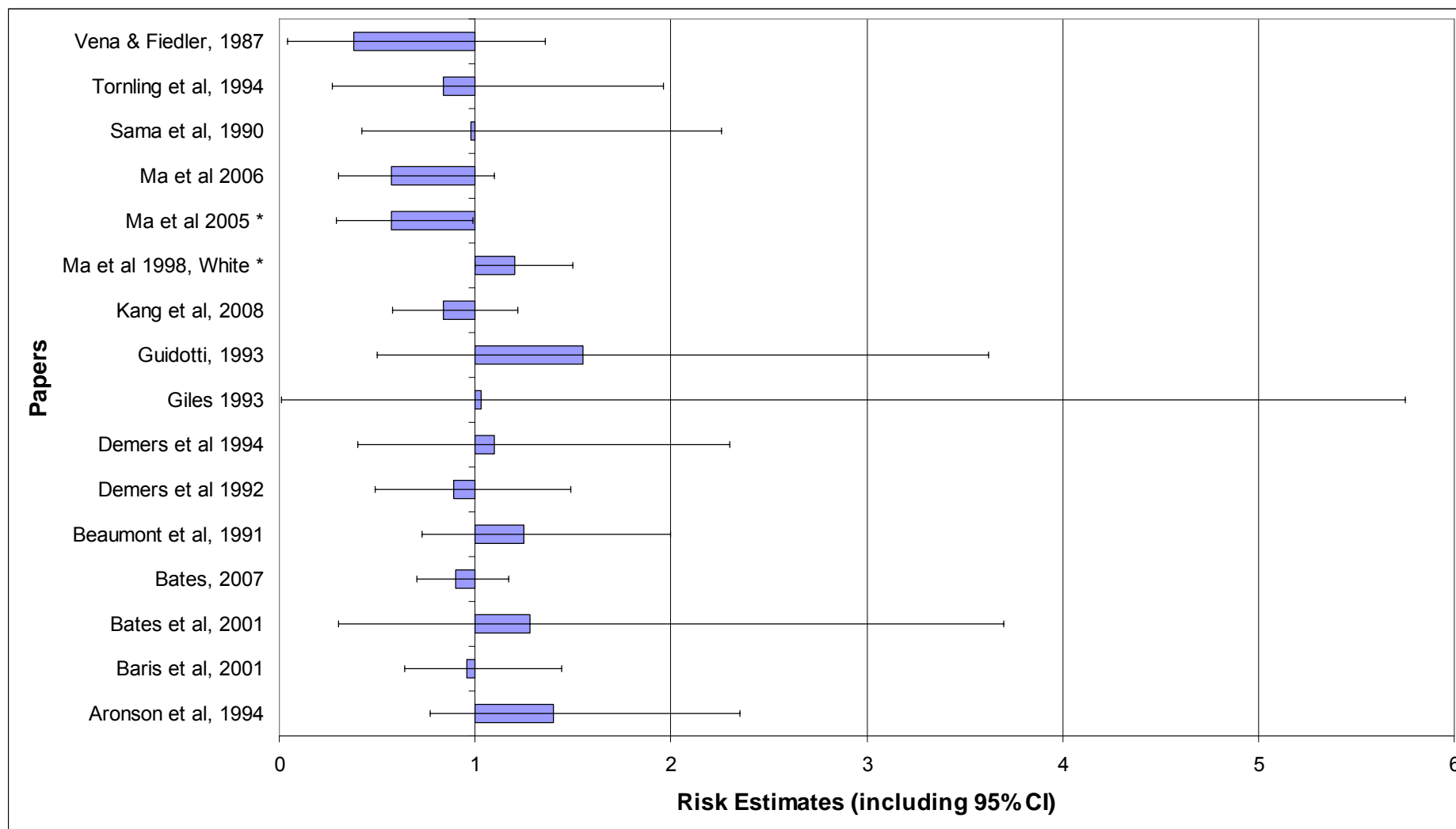
All other papers showed mixed and modest differences, some positive and some negative, none of which were statistically significant. On this basis there is no clear trend for any difference in morbidity or mortality from pancreatic cancer in firefighters compared to the general population.

Of the 16 papers, ten presented an estimate of person-years of follow-up (or equivalent). These totalled 1,529,281 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

It should be noted that the mortality paper by Ma *et al* (1998) did report a larger, positive risk estimate for black firefighters (MOR=2.0: 0.9-4.6). Based on this single study, with five diagnosed deaths, it is clearly insufficient evidence on which to base any recommendation other than the suggestion again that future evaluations of risks amongst UK firefighters should pay particular attention to the possibility of any increase of susceptibility amongst firefighters from ethnic minorities.

Both Golden *et al* (1995) and LeMasters *et al* (2006) included pancreatic cancer in their review of cancers amongst firefighters and both concluded that there was no association. The latter paper presented a non-significant summary Risk Estimate of 1.10 (0.91-1.34) based on 13 analyses in the literature. The more recent papers by Ma *et al* (2005 and 2006); Bates, (2007); and Kang *et al* (2008) would all clearly reduce this estimate, probably below 1.0. These findings reinforce the suggestion from the current review of no meaningful difference between firefighters and the general population in the risk of developing pancreatic cancer with a risk estimate of between 0.9-1.1.

Table 6 shows the evidence relating to firefighting and pancreatic cancer.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 6: Comparisons of relative risks (with 95% confidence intervals) for pancreatic cancer, derived from published studies

Table 6. Evidence relating to Fire Fighting and Pancreatic Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were 14 deaths attributed to pancreatic cancer (ICD 9, 157) in the cohort, yielding a non-significant SMR of 140 (77-235). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of these deaths. Further analysis by years since first employment, as a surrogate for exposure did not show any particular trend for mortality risk: <20 years: 103 (3-574); 20-29 years: 95 (12-344); >=30 years: 159 (80-285). An analysis by years of employment also showed no particular trend: <15 years: 175 (21-634); 15-29 years: 96 (20-279); >=30 years: 161 (74-305). Finally, an analysis of deaths by age showed a higher but non-significant risk amongst the older sub-cohort: <60 years: SMR=97 (27-249); >=60 years 170 (81-313).

Baris <i>et al.</i> , 2001	<p>Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations.</p>	++	<p>23 deaths attributed to pancreatic cancer (ICD 9, 157) yielding a non-significant SMR of 0.96 (0.64-1.44). In the analysis of duration of employment as a surrogate for exposure those who had been employed for least time were significantly more likely to die from pancreatic cancer: ≤ 9 years, SMR=2.33 (1.36-4.02); 10-19 years, SMR=0.60., (0.25-1.45); ≥ 20 years, SMR=0.49; 0.21-1.19). As an alternative measure of exposure, those who were in ladder companies were more likely to die from pancreatic cancer although none of the SMRs were significant: engine company: SMR=0.84, (0.42-1.68); ladder company: SMR=1.57 (0.51-4.88); both ladder and engine companies: SMR=0.92, (0.51-1.66). There was no meaningful pattern to the data analysed by year of recruitment: pre-1935: SMR=0.47 (0.18-1.26); 1935-1944: SMR=1.48, (0.84-2.61); post 1944: SMR=0.94, (0.45-1.97).</p>
Bates <i>et al.</i> , 2001	<p>This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).</p>	+	<p>In the whole-period analysis (1977-1996) pancreatic cancer had an SIR=1.28 (0.3-3.7) based upon three cases. Over the shorter period for which there was considered to be more complete data (1990-1996), there were also three such cancers registered yielding a higher SIR=2.17 (0.4-6.4).</p> <p>Analysis of the data by years of service did not feature this cancer. No mortality was reported for pancreatic cancer.</p>

Bates 2007	Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).	+	The occupation of fire-fighting was not significantly associated with pancreatic cancer (Odds Ratio=0.90, 0.70–1.17), based on 63 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988–1995 and 1996–2003. This yielded dichotomous results with the older registrants showing an excess OR=1.16 (0.63–2.13) and younger registrants fewer cases than expected OR=0.74 (0.38–1.45) although neither of these were significant.
Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07–0.68); diabetes mellitus (OR 0.36; 0.14–0.75); diseases of the heart (OR 0.89; 0.81–0.97); diseases of respiratory system (OR 0.63; 0.47–0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85–0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27–1.92); cirrhosis and other liver disease (OR 2.27; 1.73–2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04–1.55); and oesophagus (OR 2.04; 1.05–3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18–0.77) and the prostate (OR 0.38; 0.16–0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for pancreatic cancer was elevated, but not significantly (1.25, 0.73–2.00), based on 17 deaths. Exposure-related data for this cancer did not include confidence intervals. Time since first employment: 3–19 years: RR=2.85; 20–29 years: RR=1.74; 30–39 years: RR=1.56; 40+ years: RR=0.38. None of these values were statistically significant. Length of employment: 3–9 years: RR=1.64; 10–19 years: RR=2.78; 20–29 years: RR=1.11; 30+ years: RR=0.96. Again none of these values achieved significance.

Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Pancreatic cancer had an SMR=0.89 (0.49-1.49) based on 14 deaths. This cancer did not feature in any of the analyses for surrogates of exposure.
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Pancreatic cancer had an SIR=1.1 (0.4-2.3) based on 6 registered cases. This cancer did not feature in any of the analyses for surrogates of exposure.
Giles 1993	This paper describes the incidence of cancer between 1980-1989 in a cohort of 2,865 male firefighters employed in Melbourne, Australia between 1917 and 1989. The comparison group was the population of the state of Victoria. A total of 50 cancers were registered amongst the cohort, which did not yield a SIR significantly different from the general population. Ten named groups of cancers were described, none of which gave incidences significantly different from 1.0. There were significantly elevated incidences of "all cancers" and cancers of the colon and rectum amongst the older sub-cohort ≥ 65 years: all cancers: 2.14, (1.32-2.37); colorectal cancers: 3.65, (1.13-7.14). Neither time since start of employment or duration of employment resulted in any incidences significantly different from the comparison population.	++	One registered case of pancreatic cancer gave an SIR=1.03, (0.01-5.75).

Golden <i>et al</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain,; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	The authors concluded that there was no association between firefighting and pancreatic cancer. No risk estimate was presented.
Guidotti 1993	Cause of death was examined for two cohorts totalling 3,328 firefighters from Edmonton & Calgary (Alberta) in Canada. The firefighters were active from 1927-1987. Data was analysed over the entire cohort; by entry date; for latency as years since entry; and for duration of employment. Mortality from all causes was close to expected (SMR=96, 87-107) as was that for heart disease (SMR=110, 92-131). Statistically significant excesses were observed for: all malignant neoplasms (SMR=127, 102-155); kidney & ureter cancers (SMR=414, 166-853); and mental disorders (SMR=455, 274-711). Only isolated excesses were apparent from any of the latency or exposure-related analyses.	++	Pancreatic cancer (ICD 9 157) had an SMR=155, (50-362) but did not feature in the breakdown analysis by entry date. A series of latency analyses were reported, broken down by "exposure opportunity" which related generally to the job category in which the individual was employed. An initial all subjects analysis showed very few deaths in any of the first four sub-cohorts (2 deaths in 4) with SMRs very similar to 1 and a marked (significant) excess in the final sub-cohort). No confidence intervals were given although statistical significance was reported: <20 years: no death; 20-29 years: SMR=113; 30-39 years: SMR=0.97; 40-49 years: no deaths; 50+ years SMR=716. In the analysis by exposure index, there were isolated single deaths amongst the 1-9 index sub-cohort with most deaths in the highest exposure group (≥ 10) with 50+ years latency. The high SMR of 835 was not statistically significant.
Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Pancreatic cancer yielded an SMOR=0.84 (0.58-1.22) based on 38 registrations. A slight increasing trend was apparent in the age-stratified data although none of the values were statistically significant: 18-54: SMOR=0.70 (0.22-2.17); 55-74: SMOR=0.88 (0.47-1.65); 75+: SMOR=1.12 (0.37-3.34).

LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The meta-analysis across all forms of study, utilising a total of 13 analyses, yielded a non-significant Summary Risk Estimate of 1.10 (0.91-1.34) for pancreatic cancer. This was slightly higher than the meta-SMR of 0.98, (0.75-1.26) and the heterogeneity of the data was not significant at the 10% level.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, pancreatic cancer had a significant MOR=1.2 (1.0-1.5), based on 88 deaths. For black firefighters the MOR was 2.0 (0.9-4.6), based on 5 deaths, although this was not significant.
Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	Twelve deaths from pancreatic cancer amongst the male cohort yielded a significant SMR=0.57 (0.29-0.99). No deaths from this cancer were recorded amongst the female cohort. A subsidiary analysis of 12 deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave a slightly higher and non-significant outcome with SMR=0.7 (0.36-1.22).

Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	12 registered cases of pancreatic cancer amongst the male cohort yielded a SIR=0.57 (0.30-1.10). No cases of this cancer were recorded amongst the female cohort.
Sama <i>et al.</i> , 1990	A study using cancer registry data from Massachusetts in the USA. Samples included 315 male cancer cases between 1982 and 1986; 392 male white police officers and 29,277 State cases. The analysis included SMORS and it was identified that there was an elevated risk of melanoma (SMOR=292; 95% CI 170-503), bladder cancer (SMOR 159; 95% CI 107-414) for firefighters compared to State residents. In comparison with police officers, there was an increase risk in bladder cancer (SMOR=211; 95% CI 107-414) and non-Hodgkin's Lymphoma (SMOR=32; 95% CI 119-898). A number of difficulties with the study were identified by the researchers including the potential for underreporting of cancers.	++	Six registered cases of pancreatic cancer yielded an SMOR=98 (42-226). No further analysis of this form of cancer was reported.

Tornling <i>et al.</i> 1994	et	An investigation of cancer incidence and mortality rates in Swedish firefighters. All male firefighters employed for at least one year in the City of Stockholm between 1931 and 1981 were traced. This resulted in 1,153 individuals but a further group were already deceased so the total sample size was 1,116 males. Exposure measures were also made using a 10% sample of fire reports which was developed into an exposure index for each calendar year and each fire station. Standardised mortality ratios were calculated. The analysis identified that overall mortality was lower than expected (SMR=82; 95% CI 72-91). The cancer incidence was equal to expected but increased stomach cancer was observed (SMR=192; CI 114-304) and brain cancer (SMR 496; 95% CI 135-270).	++	Five deaths from pancreatic cancer resulted in an SMR=84 (27-196). However, the incidence of stomach cancer was slightly elevated (SIR=119, 44-260). No further analyses of pancreatic cancer were reported.
Vena Fiedler, 1987	and	A mortality study of municipal workers which all full-time employees of Buffalo USA between 1950 and 1979 for a minimum of 5 years. Individuals who had worked at least one year as a firefighter were included. At data collection this was 1,867 white male firefighters including 890 currently employed, 740 retirees, 65 who had resigned and 172 who died in service. The analysis identified that firefighters had significantly more benign neoplasms (SMR=4.17; 95% CI 1.34-9.73), malignant neoplasms including colon cancer (SMR=1.83; 95% CI 1.05-2.97), and bladder cancer (SMR=2.86; 95% CI 1.30-5.40).	++	Two deaths from pancreatic cancer amongst the cohort yielded an SMR=0.38 (0.04-1.36). Pancreatic cancer did not feature in subsidiary analyses of firefighters with estimates of exposure.

3.2.9 Laryngeal Cancer

Nine papers were identified which addressed cancer of the larynx in firefighters. These included the overlapping morbidity and mortality studies of Demers and co-workers (1992a and 1994) but not, on this occasion, the mortality study of firefighters in Florida (Ma *et al*, 2005), although the equivalent morbidity study was included. One review was identified which considered the cumulative evidence. Figure 7 shows the results from these nine papers. For clarity, the confidence intervals for the paper by Firth *et al* (1996) have been omitted because of their size (SIR=1074, 279-2776). Clearly, this individual paper stands out, not only because of the size of the apparent affect but also because it is the only one showing a positive association and the only paper to identify a statistically significant effect. The study was a population-based cancer registry study with a total of 26,207 cancer registrations. The values reported above were standardised for age and socioeconomic level. Data without the socioeconomic adjustment are not given at this level of data breakdown, although the values for protective service workers (including firefighters) and all forms of cancer are identical. The SIR for firefighters was based on four incident cases (compared to 0.4 expected).

Curiously, this finding is not replicated in the more recent study of New Zealand firefighters (Bates *et al*, 2001), which utilised data from the New Zealand Health Information Service as opposed to the New Zealand Cancer Registry used by Firth *et al* (1996). Bates and co-workers only reported cancers for which there were at least two incident cases but, with a longer data collection period (1977-1996) compared to 1972-1984), and four reported previously, a greater degree of overlap would have been expected despite differences in the nature of the studies. Commenting on this apparent discrepancy, Bates and colleagues suggest that the cases in question were probably registered in the five years prior to the start of their follow-up period.

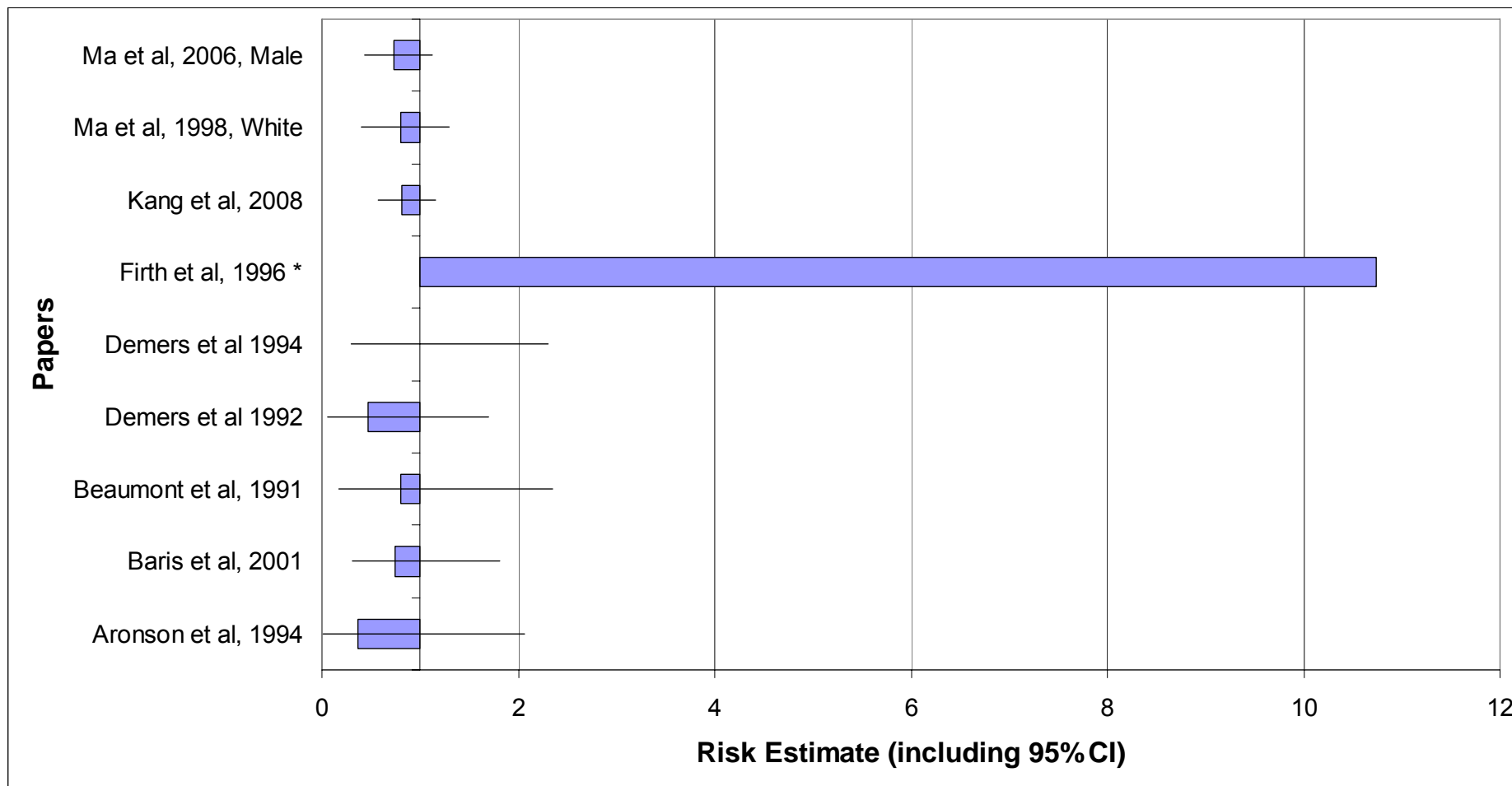
Clearly, this finding does seem to have been an isolated instance which has not been replicated, either on subsequent studies of the same population or in other studies elsewhere. On this basis there would not appear to be any reason for concern for UK firefighters.

Of the nine papers, six presented an estimate of person-years of follow-up (or equivalent). These totalled 1,387,369 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

As mentioned previously, one review paper (LeMasters *et al*, 2006) included laryngeal cancer, formulating a summary Risk Estimate from a meta-analysis of seven studies (including, again, the firefighter/police cohort of Demers, *et al*, 1992b) of 1.22 (0.87-1.70). This outcome is clearly strongly influenced by the incidence studies of Firth *et al* (1996) and the erroneously included Demers, *et al* (1992b). The latter paper reported a SIR of 1.44 (0.52-2.17) whilst the equivalent paper on the firefighter-only cohort (Demers *et al*, 1994) yielded the lower value of 0.47 (0.06-1.70).

In this instance, it would seem appropriate to disregard the findings of Firth *et al* (1996) as an outlier, and the suggestion of a positive association by LeMasters *et al* (2006), and conclude that there is no apparent positive association between laryngeal cancer and the occupation of firefighters.

Table 7 presents the data summary relating to firefighting and laryngeal cancer.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 7: Comparisons of relative risks (with 95% confidence intervals) for laryngeal cancer, derived from published studies

Table 7. Evidence relating to Fire Fighting and Laryngeal Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There was 1 death attributed to cancer of the colon (ICD 9, 161) in the cohort, yielding a non-significant SMR of 37 (1-206). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of these deaths.

Baris *et al.*, 2001 Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations. ++

Five deaths attributed to cancer of the larynx (ICD 9, 161) yielding a non-significant SMR of 0.75 (0.31-1.81). In the analysis of duration of employment as a surrogate for exposure there was no linear trend across the three categories: (≤ 9 years, SMR=0.66 (0.09-4.59); 10-19 years, SMR=0.43, (0.06-3.05); ≥ 20 years, SMR=1.08; 0.35-3.36). All the deaths were amongst those who worked in engine companies only, which yielded a non-significant excess (SMR=1.90, 0.74-4.56). There was no indication of any particular pattern of mortality related to year of hire (pre-1935: SMR=0.86 (0.22-3.45); 1935-1944: SMR=20.89, (0.22-3.55); post 1944: SMR=0.48, (0.07-3.42)).

Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for cancer of the larynx was less than 1.0, but not significantly (0.80, 0.17-2.35), based on three deaths. Exposure-related data did not include this form of cancer.
Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Laryngeal cancer had an SMR=0.47 (0.06-1.70) based on two deaths. This cancer did not feature in any of the analyses for surrogates of exposure.

Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Laryngeal cancer had an SIR=1.0 (0.03-2.3) based on five cases. This cancer did not feature in any of the analyses for surrogates of exposure.
Firth <i>et al.</i> , 1996	This study examined 26, 207 cancer registrations in New Zealand between 1972-1984. The results were broken down into occupational groups and socio-economic groups. The study used Standardised Incidence Ratios to calculate risks by cancer site and occupation. For firefighters, there were 13 cases of cancer of the larynx (SIR=1074; 95% CI 279-2776).	++	For firefighters, there were 13 cases of cancer of the larynx (SIR=1074; 95% CI 279-2776).
Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Cancer of the larynx yielded an SMOR=0.81 (0.57-1.16) based on 38 registrations. Those in the two older cohorts were more likely to have cancer of the larynx than the younger group but none of the SMORs were significant: 18-54: SMOR=0.29 (0.08-1.06); 55-74: SMOR=0.76 (0.39-1.45); 75+: SMOR=0.78 (0.25-2.45).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 1.21-1.94), non-Hodgkin lymphoma (SRE=1.58; 1.31-1.73), prostate cancer (SRE=1.28; 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 1.30-3.13).	++	The meta-analysis across all forms of study, utilising a total of 7 analyses, yielded a non-significant Summary Risk Estimate of 1.22 (0.87-1.70) for cancer of the larynx. This was higher than the meta-SMR of 0.58, (0.25-1.15) and the heterogeneity of the data was not significant at the 10% level.

Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, cancer of the larynx had an MOR=0.8 (0.4-1.3), based on 13 deaths. There were no deaths from this form of cancer amongst the cohort of black firefighters.
Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	Twenty registered cases of laryngeal cancer amongst the male cohort yielded a SIR=0.73 (0.44-1.12). No cases of this cancer were recorded amongst the female cohort.

3.2.10 Lung Cancer

Nineteen papers were identified which presented a risk estimate (with confidence intervals) for lung cancer morbidity or mortality. The main risk estimates from these are given in Figure 8. It can be seen from this that there was a broad spread of generally modestly proportioned risk estimates, either side of 1.0. Three studies yielded estimates which differed significantly from 1.0. Ma *et al* (1998) identified a modest positive association between the occupation of firefighter and lung cancer mortality (MOR=1.1, 1.0-1.2) and Ma *et al* (2006) reported a significant negative association between lung cancer morbidity and the occupation of firefighter (SIR=0.65, 0.54-0.78). However, the result which stands out from all others is the significant negative association between the incidence of lung cancer and being a firefighter reported by Donnan (1996) (SRR=0.24, 0.14-0.40) with a risk of less than a quarter. It should be noted that this apparently very low risk is not reflected in the UK occupational cancer mortality study reported by Coggon *et al* (2009) which only reported statistically significant findings. There is no indication of a significantly reduced risk of death from lung cancer amongst fire service personnel (or any other occupation) but the authors do report a significant excess of cancer of the pleura (ICD 9 163) which could be encompassed by those studies which report 'respiratory cancer' without specifying diagnostic codes (PMR=223, 102-423). This result is not presented with those for lung cancer in Figure 8 but is included in table 8.

A comparably large positive association with lung cancer morbidity and firefighting was identified by Guidotti (1993) (SMR = 1.42, 0.91-2.11) although this did not attain statistical significance. Collectively, these results would suggest morbidity and mortality rates from lung cancer are little different from the general population.

Of the 19 papers, 12 presented an estimate of person-years of follow-up (or equivalent). These totalled 1,660,681 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

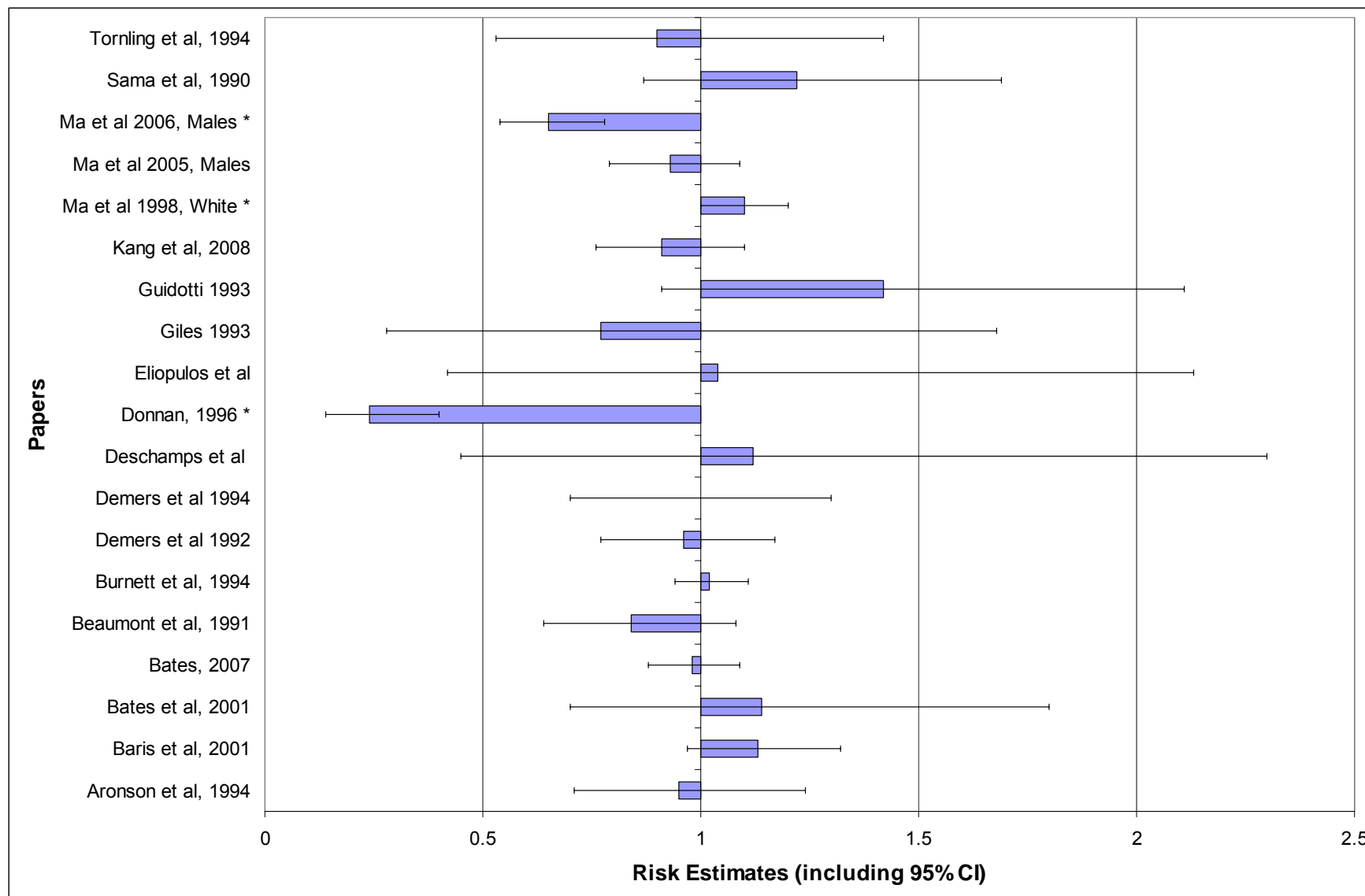
Three reviews were identified which examined the issue of lung cancer amongst firefighters. Howe and Burch (1990) identified five cohort morbidity studies and four proportionate mortality studies of lung cancer in firefighters. From the cohort studies they derived a summary Odds Ratio of 0.92, whilst the proportionate mortality studies yielded a summary Odds Ratio of 1.08, (0.95-1.23) neatly straddling 1.0. Guidotti (1995) again gives no indication of the basis of selection for the papers cited. However, the author gives particularly extensive attention to lung cancer, discussing the many other potential causal factors, together with the potential for exposure to toxic chemicals through inhalation and the increased availability and use of respiratory protection. It is suggested that any risk is generally isolated to those at highest risk (e.g. largest exposure) but that 'evidence for an association... is weak'. Nevertheless, in the final summary table, the author indicates 'likely cause' with an approximate risk estimate of 150. The author offers a final opinion (although no data are presented to support this) that the contribution due to occupation is more likely than not causal in a firefighter who does not smoke.

Some support for this can be derived from the comments of Golden *et al* (1995). The authors summarise the findings as equivocal, with no clear indication of any different risk to the general population. However, they do summarise the two papers which are stated to have identified moderately increased risks in selected groups, with the caveat that these findings were limited to current smokers only.

LeMasters *et al.* (2006) considered any excess risk of lung cancer to be “unlikely” based upon a summary Risk Estimate across all studies of 1.03 (0.97–1.08). This was similar to the mSMR and PMR estimate of 1.05 (0.96–1.14) and was based on 19 analyses. Heterogeneity amongst the studies was generally not significant at the 10% level although there was heterogeneity among PMR studies.

It appears therefore that, there is no indication of any excessive risk of lung cancer amongst firefighters with a risk estimate considered unlikely to be very different from 1.0. As with some other forms of cancer addressed earlier, the mortality study of Ma *et al.* (1998) suggested a possible differential susceptibility amongst black firefighters (MOR=0.8; 0.5-1.3), although still non-significant; and the morbidity study of Ma *et al.*, (2006) suggested an increased susceptibility in female firefighters (SIR=1.51, 0.30-4.40) although, particularly in the latter study, the low number of incident cases resulted in wide confidence intervals.

Table 8 summarises the evidence relating to firefighting and lung cancer.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 8: Comparisons of relative risks (with 95% confidence intervals) for lung cancer, derived from published studies

Table 8. Evidence relating to Fire Fighting and Lung Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were 54 deaths attributed to lung cancer (ICD 9, 162) in the cohort, yielding a non-significant SMR of 37 (1-206). Further analysis by years since first employment, as a surrogate for exposure showed no significant trend for any increased mortality risk although those with less exposure had a (non-significant) decreased risk: <20 years: 23 (1-129); 20-29 years: 103 (55-176); >=30 years: 100 (71-136). An analysis by years of employment did not show a similar trend: <15 years: 130 (56-257); 15-29 years: 85 (49-138); >=30 years: 85 (56-124). Finally, an analysis of deaths by age showed no significant risk amongst either sub-cohort: <60 years: SMR=91 (57-139); >=60 years 97 (66-137).

Baris <i>et al.</i> , 2001	<p>Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations.</p>	++	<p>162 deaths attributed to lung cancer (ICD 9, 162) yielded a non-significant SMR of 1.13 (0.97-1.32). In the analysis of duration of employment as a surrogate for exposure there was a linear trend across the three categories for a reducing risk, with those employed for the least time significantly more likely to die from lung cancer: (≤ 9 years, SMR=1.52 (1.16-2.01); 10-19 years, SMR=1.10., (0.92-1.56); ≥ 20 years, SMR=0.89; 0.68-1.15). As an alternative measure of exposure, those who were in engine companies, either alone or also in ladder companies were slightly more likely to die from lung cancer than those in ladder companies alone although none of the SMRs were significant, which was seen as consistent with the suggestion that members of this sub-cohort would have been likely to have received greater exposure to possibly toxic substances than others. (engine company: SMR=1.18, (0.93-1.51); ladder company: SMR=0.71 (0.36-1.43); both ladder and engine companies: SMR=1.13, (0.91-1.40)). There were suggestions that those recruited earlier were likely to show greater mortality than those recruited more recently. (pre-1935: SMR=1.30 (0.97-1.73); 1935-1944: SMR=1.15, (0.89-1.47); post-1944: SMR=1.02 (0.78-1.33)).</p>
Bates <i>et al.</i> , 2001	<p>This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).</p>	+	<p>In the whole-period analysis (1977-1996) lung cancer had an SIR=1.14 (0.7-1.8) based upon 17 cancers. Over the shorter period for which there was considered to be more complete data (1990-1996), there were seven such cancers yielding a lower SIR=0.82 (0.3-1.7).</p> <p>Analysis of the data by years of paid service only, demonstrated an apparent trend for an increased incidence although none of the SIRs were statistically significant: 0-10 years: SIR=0.93, 0.2-2.7; 11-20 years: SIR=1.45, 0.4-3.7; >20 years: SIR=1.52, 0.7-3.0. A similar but smaller trend was observed amongst paid and volunteer firefighters combined. Mortality over the whole period had a reduced but non-significant SMR=0.86 (0.4-1.6).</p>

Bates 2007	Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).	+	The occupation of fire-fighting was not significantly associated with lung cancer (Odds Ratio=0.98, 0.88–1.09), based on 495 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988–1995 and 1996–2003. This suggested a lower risk than amongst their peers with the older registrants showing an OR=0.85 (0.64–1.14) and younger registrants OR=0.77 (0.56–1.05) although neither of these were significant.
Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07–0.68); diabetes mellitus (OR 0.36; 0.14–0.75); diseases of the heart (OR 0.89; 0.81–0.97); diseases of respiratory system (OR 0.63; 0.47–0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85–0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27–1.92); cirrhosis and other liver disease (OR 2.27; 1.73–2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04–1.55); and oesophagus (OR 2.04; 1.05–3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18–0.77) and the prostate (OR 0.38; 0.16–0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for lung cancer was lower than expected, but not significantly (0.84, 0.64–1.08), based on 60 deaths. Exposure-related data for this cancer did not include confidence intervals. Time since first employment: 3–19 years: RR=0.37; 20–29 years: RR=0.71; 30–39 years: RR=0.97; 40+ years: RR=0.89, none of which were statistically significant. Length of employment: 3–9 years: RR=0.82; 10–19 years: RR=0.63; 20–29 years: RR=0.79; 30+ years: RR=0.98. Again, none of these values achieved significance.
Burnett <i>et al.</i> , 1994	Assessment of mortality rates for firefighters using information from 27 USA states between 1984–1990. In total 5,744 deaths in white male firefighters were reviewed and analysis was based on proportionate mortality ratios comparing deaths from specific causes as compared to all causes in firefighters. The study identified there was increased levels of malignant neoplasms (PMR=110; 95% CI 106–114), rectal cancer (PMR=148; 95% CI 105–205). skin cancer (PMR=163; 95% CI 115–223). kidney cancer (PMR=144; 95% CI 108–189), lymphatic and haematopoietic cancers (PMR=130 95% CI 111–151) and multiple myeloma (PMR=148; 95% CI 102–207).	++	The study identified no excess risk of lung cancer mortality: PMR=102, 94–111.

Coggon <i>et al.</i> , 2009	This Report describes an analysis of mortality by occupation in England and Wales during 1991–2000. Analysis was based on all deaths in England and Wales during 1991–2000 at ages 16–74 years. Associations of cause of death with occupation were characterised by proportional mortality ratios (PMRs) with associated 95 per cent confidence intervals (95%CI). All PMRs were standardised for age in five-year bands, and most were standardised also for social class. Analysis was based on the underlying cause of death as recorded on the death certificate. Data were only reported where an analysis showed a PMR significantly higher or lower than 1.0.	+	An excess of cancer of the pleura was reported for “fire service personnel”, based on seven deaths (PMR=268, 108-553).
Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Lung cancer had an SMR=0.96 (0.77-1.17) based on 95 deaths. This cancer did not feature in any of the analyses for surrogates of exposure.
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. Comparison group was 1878 police officers. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Lung cancer had an SIR=1.0 (0.7-1.3) based on 45 deaths. An analysis by duration of exposed employment showed a (non-significant) tendency for an enhanced risk amongst those employed for less time: <10 years: 1.4 (0.6-2.7); 10-19 years: 1.4 (0.7-2.7); 20-29 years: 0.9 (0.6-1.3); 30+ years: 0.4 (0.1-1.5). A similar analysis by years since first employment showed no such trend: <20 years: SIR=0.0 (0.0-2.5); 20-29 years: 1.5 (0.7-2.6); SIR=30+ years: SIR=0.9 (0.6-1.3).

Deschamps <i>et al.</i> , 1995	Cohort of 830 firefighters with a minimum service of five years, studied over a 14 year period from January 1977 to Jan 1991. When compared to the average French male, the Paris fire-fighters were found to have a far lower overall mortality (SMR = 0.52 [0.35-0.75]). None of the cause specific SMRs were significantly different from unity. However a greater number of deaths than expected was observed for genitourinary cancer (SMR = 3.29), digestive cancer (SMR = 1.14), respiratory cancer (SMR = 1.12) and 'cerebrovascular disease' (SMR = 1.16). The low overall SMR observed was consistent with the healthy worker effect.	+	The authors reported lung cancer clustered with respiratory cancers (ICD 9, 160-165) for which they reported an SMR=1.12 (0.45-2.30). No exposure-related analysis was reported in this study.
Donnan, 1996	This reported the study of mortality and cancer incidence amongst a UK cohort of 5,568 firefighters drawn from five Brigades and compared against statistics for adult males from England and Wales. The cohort was followed for approximately 30 years (1965-1993). With few exceptions, deaths from the various causes studied were significantly lower than expected. This included deaths from all causes: SMR=0.67 (0.62-0.72); all circulatory diseases: SMR=0.70 (0.60-0.80); CHD: SMR=0.72 (0.61-0.85); all cancers: SMR=0.72 (0.60-0.86); and lung cancer: SMR=0.47 (0.32-0.67). Cancer registrations were also generally significantly lower with specific Standardised Registration Ratios (SRR) of: skin cancer: SRR=0.63 (0.39-0.97); lung cancer: SRR=0.24 (0.14-0.40); colon and rectal cancer: SRR=0.56 (0.32-0.93); bladder cancer: SRR=0.72 (0.36-1.26); stomach cancer: SRR=0.42 (0.17-0.88); and prostate cancer: SRR=0.31 (0.10-0.72).	++	Based on 26 registered cases, registrations of lung cancer SRR=0.24 (0.14-0.40) were significantly lower than the England and Wales statistic. In the sub-group analyses reported, SRRs for each five-year period of registration were also all significantly less than expected; the incidence was depressed within each age group, although not always significantly so and was markedly lower amongst those who had ever been an officer (0.10 v 0.30). Further analyses reported a marginally lower incidence amongst those who entered the service prior to the onset of the study (0.25 v 0.19); and a trend towards higher levels amongst those with fewer years of service (data only presented graphically).
Eliopoulos <i>et al</i> 1984	973 fire fighters employed by the Western Australian Fire Brigade between 1 October 1939 and 31 December 1978 were successfully followed up to 31 December 1978. Mortality from all causes was less than expected (SMR=0.80, 0.67 to 0.96). No specific causes of death attained statistical significance and there were no indications that mortality was associated with duration of employment.	++	The SPMR for respiratory cancer, based on seven deaths, was 0.84 (0.33-1.71). There was no sub-cohort analysis of these deaths reported.

Giles 1993	This paper describes the incidence of cancer between 1980-1989 in a cohort of 2,865 male firefighters employed in Melbourne, Australia between 1917 and 1989. The comparison group was the population of the state of Victoria. A total of 50 cancers were registered amongst the cohort, which did not yield a SIR significantly different from the general population. Ten named groups of cancers were described, none of which gave incidences significantly different from 1.0. There were significantly elevated incidences of "all cancers" and cancers of the colon and rectum amongst the older sub-cohort ≥ 65 years: all cancers: 2.14, (1.32-2.37); colorectal cancers: 3.65, (1.13-7.14). Neither time since start of employment or duration of employment resulted in any incidences significantly different from the comparison population.	++	Six registered cases of lung cancer gave an SIR=0.77, (0.28-1.68).
Golden <i>et al</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain,; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	The authors summarise the findings as equivocal, with no clear indication of any different risk to the general population although one paper is referred to which is stated to have identified moderately increased risks in selected groups of current smokers only.
Guidotti 1993	Cause of death was examined for two cohorts totalling 3,328 firefighters from Edmonton & Calgary (Alberta) in Canada. The firefighters were active from 1927-1987. Data was analysed over the entire cohort; by entry date; for latency as years since entry; and for duration of employment. Mortality from all causes was close to expected (SMR=96, 87-107) as was that for heart disease (SMR=110, 92-131). Statistically significant excesses were observed for: all malignant neoplasms (SMR=127, 102-155); kidney & ureter cancers (SMR=414, 166-853); and mental disorders (SMR=455, 274-711). Only isolated excesses were apparent from any of the latency or exposure-related analyses.	++	Lung cancer (ICD 9 162) had an SMR=142, (91-211). Analysis by entry date showed (non-significant) elevated risks within most sub-cohorts: <1920: SMR=223; 1920s: SMR=95; 1930s: no SMR; 1940s: SMR=155; 1950s: SMR=118; 1960s: SMR=169; 1970s: SMR=261. A series of latency analyses were reported, broken down by "exposure opportunity" which related generally to the job category in which the individual was employed. An initial all subjects analysis showed a mix of SMRs above and below 100, none of which were statistically significant: <20 years: SMR=192; 20-29 years: SMR=95; 30-39 years: SMR=173; 40-49 years: SMR=97;

50+ years SMR=175. In the analysis by exposure index, isolated small numbers of deaths amongst the less exposed sub-cohorts all yielded non-significant SMRs and, even amongst the highest exposed sub-cohort (Index ≥ 10), all SMRs were non-significant: <20 years: SMR=99; 20-29 years: SMR=96; 30-39 years: SMR=134; 40-49 years: SMR=114; 50+ years SMR=202.

For lung cancer the pooled SMR/PMR values were 0.92/1.08, neither of which were significant.

Howe and Burch, 1990 Review paper from 1990. Looked at 'all cancers' and "those specific cancers which individual studies have reported to show an association with the occupation of fire fighter". Lung, colon, brain, malignant myeloma and multiple myeloma were chosen. Studies with any demonstrable major bias were excluded (not listed). Note that much work on testicular cancer (e.g. early Bates *et al* study from 1995) would not be covered. Pooled estimate showed sig all cause reduced risk (0.92, 0.85-0.98) in SMR but increased (1.09, 1.01-1.17) PMR which authors dismiss as artefact of healthy worker effect. For lung cancer the pooled SMR/PMR values were 0.92/1.08, neither of which were sig. Pooling colon cancer studies again yielded non-sig effects (SMR, 1.12, PMR, 1.06). For brain tumours the pooled SMR of 1.43 and PMR of 1.45 narrowly missed sig (CI, 0.93-2.12 & 0.95-2.12 respectively). Authors point out that the main study unsupportive of an effect related primarily to pre-WW2 exposures when, it is hypothesised, exposures to carcinogens would have been less. No dose-response relationship has been seen but causation is seen as biologically plausible. Sig increased risk of malignant melanoma based on pooled estimate of 1.73 from 5 studies. Exposure-response relationship also seen. However, authors regard causal connection as implausible with high risk of confounding. For multiple myeloma, increased pooled risk of 1.51 is not sig. This value is distorted by high value (10.00) in 1 study.

Kang *et al.*, 2008 A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources. ++

Lung cancer yielded an SMOR=0.91 (0.76-1.10) based on 379 registrations. No trend was apparent in the age-stratified data: 18-54: SMOR=0.82 (0.44-1.50); 55-74: SMOR=1.03 (0.74-1.43); 75+: SMOR=1.05 (0.63-1.76).

LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13).	++	The meta-analysis across all forms of study, utilising a total of 13 analyses, yielded a significant Summary Risk Estimate of 1.03 (0.97 –1.08) for lung cancer. This was similar to the meta-SMR/PMR estimate of 1.05, (0.96-1.14) and the heterogeneity of the data was not significant at the 10% level, although there was heterogeneity among PMR studies.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, lung cancer had a slightly elevated mortality risk which was statistically significant: MOR=1.1 (1.0-1.2), based on 633 deaths. For black firefighters the MOR was 0.8 (0.5-1.3).
Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	155 deaths from lung cancer amongst the male cohort yielded an SMR=0.93 (0.79-1.09). Three deaths from this cancer amongst the female cohort gave an SMR=2.16 (0.43-6.31). A subsidiary analysis of 134 deaths amongst male firefighters with the longest estimated exposure (registered 1972-1976) gave a very similar outcome with SMR=0.96 (0.80-1.13).

Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. 36,813 professional firefighters were identified (94.5% male, 5.5% female). The study identified 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancer (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	128 registered cases amongst the male cohort yielded a significantly reduced risk of being diagnosed with lung cancer SIR=0.65 (0.54-0.78). Three cases of this cancer were recorded amongst the female cohort (SIR=1.51, 0.30-4.40).
Sama <i>et al.</i> , 1990	A study using cancer registry data from Massachusetts in the USA. Samples included 315 male cancer cases between 1982 and 1986; 392 male white police officers and 29,277 State cases. The analysis included SMORS and it was identified that there was an elevated risk of melanoma (SMOR=292; 95% CI 170-503), bladder cancer (SMOR 159; 95% CI 107-414) for firefighters compared to State residents. In comparison with police officers, there was an increase risk in bladder cancer (SMOR=211; 95% CI 107-414) and non-Hodgkin's Lymphoma (SMOR=32; 95% CI 119-898). A number of difficulties with the study were identified by the researchers including the potential for underreporting of cancers.	++	The analysis included SMORS and it was identified that there was an elevated risk (non-significant) of lung cancer in comparison to all state cases (SMOR=122, 87-169).
Tornling <i>et al.</i> 1994	An investigation of cancer incidence and mortality rates in Swedish firefighters. All male firefighters employed for at least one year in the City of Stockholm between 1931 and 1981 were traced. This resulted in 1,153 individuals but a further group were already deceased so the total sample size was 1,116 males. Exposure measures were also made using a 10% sample of fire reports which was developed into an exposure index for each calendar year and each fire station. Standardised mortality ratios were calculated. The analysis identified that overall mortality was lower than expected (SMR=82; 95% CI 72-91). The cancer incidence was equal to expected but increased stomach cancer was observed (SMR=192; CI 114-304) and brain cancer (SMR 496; 95% CI 135-270).	++	18 deaths from lung cancer resulted in an SMR=90 (53-142) and 16 registered cases yielded a very similar SIR=89 (51-145). No further analyses of lung cancer were reported.

3.2.11 Skin Cancer

Interpretation of data on skin cancer is complicated by the fact that some studies have not specified ICD codes, others have used ICD 9 Code 172 or ICD 10 Code C43 (malignant melanoma) whilst others have used ICD 9 173 or ICD 10 C44 (other malignant neoplasm's). One study (Sama *et al*, 1990) confusingly refers to the skin cancer as melanoma but attributes the ICD 9 Code 173 to it. Where authors have indicated a code, an initial inspection of the risk estimates suggested that there was no consistent pattern differentiating the two categories and therefore a decision was made to combine the results. One paper reported risk estimates for the two codes (ICD 9, 172 & 173) separately. Thus, Tomling *et al* (1994) reported an SMR of 79 (9-287) for malignant melanoma and an SMR of 151 (49-353) for skin cancers excluding melanomas. Neither are included in Figure 9, which shows the remainder of the risk estimates for which a confidence interval was provided. One further paper (Feuer and Rosenman, 1986) reported positive associations when firefighters were compared to other white males in the state (PMR=1.90) or to white US males (PMR=2.70). This latter value attained statistical significance but no confidence interval was reported. In this instance, the comparator of other white males living in the same state would seem the most appropriate.

It will be seen from Figure 9 that the study of Sama *et al* (1990) of morbidity amongst Massachusetts firefighters over a four year period (1982-1986) provides what has been regarded by some authors as an outlier, with an SMOR of 292 (170-503) which, until recently, was almost twice that of the next largest estimate. However, the recent study of cancer mortality in England and Wales by Coggon and co-authors (Coggon *et al*, 2009) presents a similarly-sized risk estimate (PMR=268, 108-553), albeit one based on only seven deaths amongst fire service personnel (which might have included non-operational staff). It should also be noted that the estimate is based upon PMR calculations and therefore might be distorted by a healthy worker effect amongst firefighters, where deaths in general are lower than would be expected.

This risk estimate was one of six attaining statistical significance, the others being the papers by Ma *et al*, 1998; Burnett *et al*, 1994; and Bates *et al*, 2007 which all also reported a positive association and that from Donnan (1996) which presented a significant negative association. This latter paper, in contrast to the other UK-based study, presents the lowest estimate of all the studies found (excluding that of Guidotti, 1993).

The paper by Aronson *et al* (1994) also showed a sizeable negative association (SMR=73, 9-263) albeit based on only two deaths. That by Guidotti (1993) is potentially misleading as the study failed to identify any cases where 1.1 had been expected. It is included in the graph as the author nevertheless presented a confidence interval around this risk estimate of zero. In contrast to these papers which identified few deaths from skin cancer, the mortality risk estimate of Burnett *et al* (1994) (PMR=163, 115-223) was based upon 38 deaths whilst that from Donnan (1996) included 35 observed cancers (non-melanoma).

On balance, it would seem that there is a positive association between the risk of skin cancer and the occupation of firefighter, with two papers presenting risk estimates well in excess of 2.0. However, despite these papers, the general impression would seem to be a modest positive association with an estimated relative risk of 1.2-1.3.

Of the 17 papers, nine presented an estimate of person-years of follow-up (or equivalent). These totalled 1,607,169 person-years, including the two large studies

of the mortality and morbidity of Florida firefighters (Ma *et al.* 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

Chronologically, the first review paper identified was that of Howe and Burch (1990) who identified five papers which predate much of the work reported here. These five papers (which included one which found no mortalities and consequently had a comparatively wide confidence interval) yielded a summary risk estimate of 1.73 (1.03-2.74). However, the authors questioned whether this was genuinely a causal association because of what they saw as a lack of any apparent occupational cause.

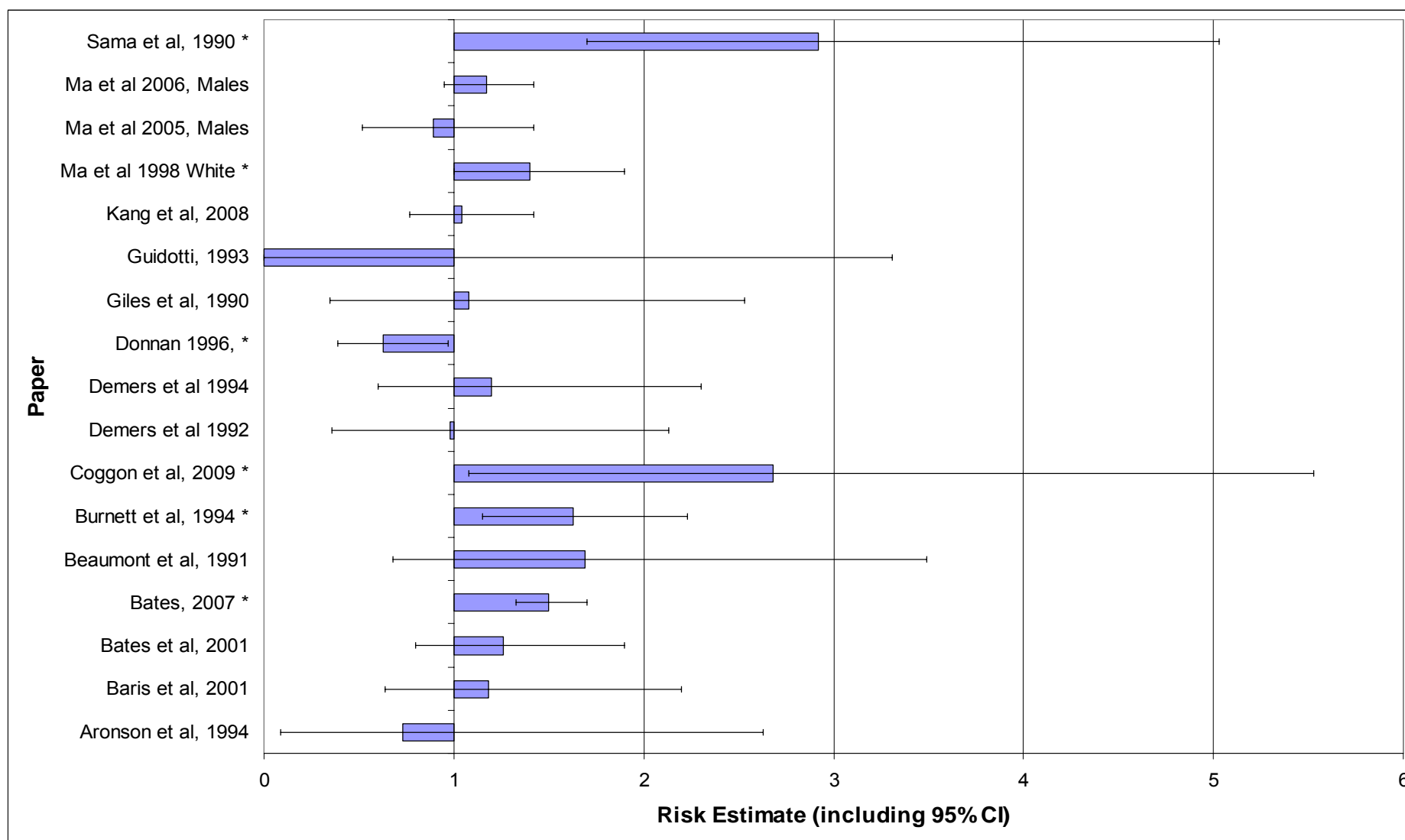
The next review was that by Golden *et al* (1995) who again showed a strongly consistent positive association with six out of eight studies showing a positive effect; one showing an effect virtually indistinguishable from normal (SMR=98) and only one showing a clear negative association (the paper by Aronson *et al*, 1994). However, the authors of this review did conclude that an association was biologically plausible, given potential exposures to carcinogenic materials within the products of combustion.

LeMasters *et al* (2006) identified eight estimates of risk which they used in formulating their summary risk estimate of 1.39 (1.10-1.73). This value was compiled separately from malignant melanoma, for which a different Summary Risk Estimate (1.32, 1.10-1.57) was computed. However, in preparing the first estimate they appear to have utilised some authors who combined the two codes (e.g. Baris *et al*, 2001) others who actually used melanoma (e.g. Burnett *et al*, 1994); further papers where the code used was not specified (e.g. Beaumont *et al*, 1991) and others who clearly differentiated the two codes. As the resultant outcomes are not dissimilar this confusion is not however of any great significance. As with other forms of cancer, the more recent studies of Ma and co-workers (2005, 2006); Bates (2007); and Kang *et al* (2008) and the UK reports by Donnan (1996) and Coggon *et al* (2009) were not included.

The mortality and morbidity studies of Ma *et al* (2005 and 2006) produced conflicting results which effectively negate each other, whilst the study of Kang *et al* (2008) showed a modest positive increase (SMOR=1.04, 0.77-1.42). The study by Bates (2007) identified a larger, statistically significant positive association (OR=1.50, 1.33-1.70). With 323 firefighters diagnosed with skin melanoma this would seem to be a reasonably powerful study, as shown by the comparatively narrow confidence interval and would more than offset the impact of the negative finding by Donnan with 35 incident cases. Although the risk estimate presented by Coggon and co-workers (2009) is greater, this is offset by the relatively small number of cases within this sample.

On balance, there would appear to be relatively recent consistency suggesting a positive association between firefighting and skin cancer, probably of the order of 1.3-1.4, but clearly less than 2.0.

Table 9 summarises the evidence relating to firefighting and skin cancer.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 9: Comparisons of relative risks (with 95% confidence intervals) for skin cancer, derived from published studies
Table 9. Evidence relating to Fire Fighting and Skin Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were two deaths attributed to malignant melanoma (ICD 9, 172) in the cohort, yielding a non-significant SMR of 73 (9-263). Further analysis by years since first employment, as a surrogate for exposure showed no significant trend for any increased mortality risk: <20 years: 95 (2-531); 20-29 years: 130 (3-724); >=30 years: 0 (0-397). An analysis by years of employment also showed no trend: <15 years: 110 (3-612); 15-29 years: 90 (2-502); >=30 years: 0 (0-527). Finally, an analysis of deaths by age showed no significant risk amongst either sub-cohort: <60 years: SMR=94 (11-341); >=60 years 0 (0-586).

Baris <i>et al.</i> , 2001	<p>Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations.</p>	++	<p>Ten deaths attributed to skin cancer (ICD 9, 172-173) yielded a non-significant SMR of 1.18 (0.64-2.20). In the analysis of duration of employment as a surrogate for exposure there was no linear trend across the three categories: (≤ 9 years, SMR=0.75 (0.19-3.01); 10-19 years, SMR=1.70., (0.71-4.09); ≥ 20 years, SMR=1.05; 0.34-3.26). As an alternative measure of exposure, those who were in engine companies alone were more likely to die from skin cancer, which was seen as consistent with the suggestion that members of this sub-cohort would have been more likely to have received greater exposure to possibly toxic substances than others. (engine company: SMR=1.89, (0.84-4.20); ladder company: no deaths; both ladder and engine companies: SMR=0.68, (0.22-2.11)). There was no consistent trend in relation to period of recruitment (pre-1935: SMR=1.45 (0.46-4.48); 1935-1944: SMR=0.43, (0.06-3.03); post 1944: SMR=1.49, (0.67-3.32)).</p>
Bates <i>et al.</i> , 2001	<p>This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).</p>	+	<p>In the whole-period analysis (1977-1996) skin cancer had an SIR=1.26 (0.8-1.9) based upon 23 cancers. Over the shorter period, for which there was considered to be more complete data (1990-1996), there were 15 such cancers yielding a similar SIR=1.49 (0.8-2.5).</p> <p>Analysis of the data by years of paid service only, demonstrated an apparently stable but increased incidence although none of the SIRs were statistically significant: 0-10 years: SIR=1.72, 0.7-3.5; 11-20 years: SIR=1.75, 0.6-3.8; >20 years: SIR=1.67, 0.6-3.6. A similar trend was observed amongst paid and volunteer firefighters combined. Mortality over the whole period had a reduced but non-significant SMR=0.65 (0.1-2.4).</p>

Bates 2007	Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).	+	The occupation of fire-fighting was significantly associated with melanoma of the skin (Odds Ratio=1.50, 1.33-1.70), based on 323 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988-1995 and 1996-2003. This yielded similar results with the older registrants showing a smaller significant excess (OR=1.55, 1.19-2.01) than the younger registrants (OR=1.86, 1.51-2.29).
Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for cancer of the stomach was elevated, but not significantly (1.69, 0.68-3.49), based on 7 deaths. Exposure-related data was not presented for this form of cancer.
Burnett <i>et al.</i> , 1994	Assessment of mortality rates for firefighters using information from 27 USA states between 1984-1990. In total 5,744 deaths in white male firefighters were reviewed and analysis was based on proportionate mortality ratios comparing deaths from specific causes as compared to all causes in firefighters. The study identified there was increased levels of: malignant neoplasms (PMR=110; 95% CI 106-114); rectal cancer (PMR=148; 95% CI 105-205); skin cancer (PMR=163; 95% CI 115-223); kidney cancer (PMR=144; 95% CI 108-189); lymphatic and haematopoietic cancers (PMR=130 95% CI 111-151); and multiple myeloma (PMR=148; 95% CI 102-207).	++	The study identified there was an increased risk of skin cancer (PMR=163, 115-223).

Coggon <i>et al.</i> , 2009	This Report describes an analysis of mortality by occupation in England and Wales during 1991–2000. Analysis was based on all deaths in England and Wales during 1991–2000 at ages 16–74 years. Associations of cause of death with occupation were characterised by proportional mortality ratios (PMRs) with associated 95 per cent confidence intervals (95% CIs). All PMRs were standardised for age in five-year bands, and most were standardised also for social class. Analysis was based on the underlying cause of death as recorded on the death certificate. Data were only reported where an analysis showed a PMR significantly higher or lower than 1.0. An excess of non-melanoma of the skin was reported for “fire service personnel”, based on seven deaths (PMR=268, 108-553).	+	An excess of non-melanoma of the skin was reported for “fire service personnel”, based on seven deaths (PMR=268, 108-553).
Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Skin cancer (ICD 9 172, 173) had an SMR=0.98 (0.36-2.13) based on 6 deaths. This cancer did not feature in any of the analyses for surrogates of exposure.
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Skin cancer (ICD9, 172) had an SIR=1.2 (0.6-2.3) based on 9 deaths. An analysis by duration of exposed employment showed no particular pattern: <10 years: 0.0 (0.0-2.6); 10-19 years: 2.3 (0.6-5.8); 20-29 years: 1.1 (0.3-2.7); 30+ years: 2.4 (0.1-13). A similar analysis by years since first employment also showed no particular pattern: <20 years: SIR=1.3 (0.2-4.4); 20-29 years: 1.2 (0.1-4.3); SIR=30+ years: SIR=1.2 (0.4-2.8).

Donnan, 1996	<p>This reported the study of mortality and cancer incidence amongst a UK cohort of 5,568 firefighters drawn from five Brigades and compared against statistics for adult males from England and Wales. The cohort was followed for approximately 30 years (1965-1993). With few exceptions, deaths from the various causes studied were significantly lower than expected. This included deaths from all causes: SMR=0.67 (0.62-0.72); all circulatory diseases: SMR=0.70 (0.60-0.80); CHD: SMR=0.72 (0.61-0.85); all cancers: SMR=0.72 (0.60-0.86); and lung cancer: SMR=0.47 (0.32-0.67). Cancer registrations were also generally significantly lower with specific Standardised Registration Ratios (SRR) of: skin cancer: SRR=0.63 (0.39-0.97); lung cancer: SRR=0.24 (0.14-0.40); colon and rectal cancer: SRR=0.56 (0.32-0.93); bladder cancer: SRR=0.72 (0.36-1.26); stomach cancer: SRR=0.42 (0.17-0.88); and prostate cancer: SRR=0.31 (0.10-0.72).</p>	++	<p>Based on 35 registered cases, registrations of skin cancer other than melanoma were significantly lower than the England and Wales statistic (SRR=0.63, 0.39-0.97).</p> <p>In the sub-group analyses reported, SRRs for each five-year period of registration and within each decile age group, the incidence was generally depressed, although not significantly so. It was also slightly higher amongst those who had ever been an officer (0.72 v 0.60). Further analyses reported a marginally higher incidence amongst those who entered the service prior to the onset of the study (0.67 v 0.33).</p>
Giles 1993	<p>This paper describes the incidence of cancer between 1980-1989 in a cohort of 2,865 male firefighters employed in Melbourne, Australia between 1917 and 1989. The comparison group was the population of the state of Victoria. A total of 50 cancers were registered amongst the cohort, which did not yield a SIR significantly different from the general population. Ten named groups of cancers were described, none of which gave incidences significantly different from 1.0. There were significantly elevated incidences of "all cancers" and cancers of the colon and rectum amongst the older sub-cohort ≥ 65 years: all cancers: 2.14, (1.32-2.37); colorectal cancers: 3.65, (1.13-7.14). Neither time since start of employment or duration of employment resulted in any incidences significantly different from the comparison population.</p>	++	<p>Five registered melanoma cases gave an SIR=1.08, (0.35-2.53).</p>

Golden <i>et al</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain,; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	The authors identified what they regarded as a strongly consistent positive association between skin cancer and being a firefighter, with six out of eight studies showing a positive effect, which they concluded was biologically plausible, given potential exposures to carcinogenic materials within the products of combustion.
Guidotti 1993	Cause of death was examined for two cohorts totalling 3,328 firefighters from Edmonton & Calgary (Alberta) in Canada. The firefighters were active from 1927-1987. Data was analysed over the entire cohort; by entry date; for latency as years since entry; and for duration of employment. Mortality from all causes was close to expected (SMR=96, 87-107) as was that for heart disease (SMR=110, 92-131). Statistically significant excesses were observed for: all malignant neoplasms (SMR=127, 102-155); kidney & ureter cancers (SMR=414, 166-853); and mental disorders (SMR=455, 274-711). Only isolated excesses were apparent from any of the latency or exposure-related analyses.	++	There were no reported deaths from skin cancer (ICD 9 172) resulting in an SMR=0.0, (0-331). This form of cancer did not therefore feature in any breakdown analyses by entry date or other exposure surrogates.

Howe and Burch, 1990	<p>Review paper from 1990. Looked at 'all cancers' and "those specific cancers which individual studies have reported to show an association with the occupation of fire fighter". Lung, colon, brain, malignant myeloma and multiple myeloma were chosen. Studies with any demonstrable major bias were excluded (not listed). Note that much work on testicular cancer (e.g. early Bates <i>et al</i> study from 1995) would not be covered. Pooled estimate showed sig all cause reduced risk (0.92, 0.85-0.98) in SMR but increased (1.09, 1.01-1.17) PMR which authors dismiss as artefact of healthy worker effect. For lung cancer the pooled SMR/PMR values were 0.92/1.08, neither of which were sig. Pooling colon cancer studies again yielded non-sig effects (SMR, 1.12, PMR, 1.06). For brain tumours the pooled SMR of 1.43 and PMR of 1.45 narrowly missed sig (CI, 0.93-2.12 & 0.95-2.12 respectively). Authors point out that the main study unsupportive of an effect related primarily to pre-WW2 exposures when, it is hypothesised, exposures to carcinogens would have been less. No dose-response relationship has been seen but causation is seen as biologically plausible. Sig increased risk of malignant melanoma based on pooled estimate of 1.73 from 5 studies. Exposure-response relationship also seen. However, authors regard causal connection as implausible with high risk of confounding. For multiple myeloma, increased pooled risk of 1.51 is not sig. This value is distorted by high value (10.00) in 1 study.</p>	<p>The authors calculated a pooled SMR/PMR estimate for malignant melanoma of 1.73 (1.03-2.74). However, despite this significant finding the authors concluded that there was "little evidence to support the causality of the association".</p>
Kang <i>et al.</i> , 2008	<p>A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.</p>	<p>++</p> <p>Skin melanoma yielded an SMOR=1.04 (0.77-1.42) based on 78 registrations. A slight trend was apparent in the age-stratified data which suggested a reduction in risk with age: 18-54: SMOR=0.97 (0.51-1.88); 55-74: SMOR=0.61 (0.33-1.13); 75+: SMOR=0.35 (0.13-0.91). The reduction in risk in the oldest sub-cohort indicated a significantly lower risk than expected.</p>

LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The authors suggested that there was a possible risk of skin cancer associated with being a firefighter. Their meta-analysis across all forms of study, utilising a total of 8 analyses, yielded a significant Summary Risk Estimate of 1.39 (1.10 –1.73). This was slightly lower than the meta-SMR and PMR of 1.44, (1.10-1.87) derived on the basis of PMR studies and the heterogeneity of the data was not significant at the 10% level.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, melanoma of the skin had a significant MOR=1.4 (1.0-1.9), whilst that for other forms of skin cancer was non-significant: MOR=1.0 (0.5-1.9), based on 35 and 9 deaths respectively. For black firefighters there were no deaths from either category of skin cancer.
Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	17 deaths from skin cancer amongst the male cohort yielded an SMR=0.89 (0.52-1.42). No deaths from this cancer were recorded amongst the female cohort. A subsidiary analysis of 15 deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave a higher risk with SMR=1.21 (0.68-2.00).

Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	99 registered cases of skin cancer (ICD 10, C44) amongst the male cohort yielded a SIR=1.17 (0.95-1.42). Five cases of this cancer were recorded amongst the female cohort yielding an SIR=3.01 (0.97-7.03). Both risk estimates narrowly failed to attain statistical significance.
Sama <i>et al.</i> , 1990	A study using cancer registry data from Massachusetts in the USA. Samples included 315 male cancer cases between 1982 and 1986; 392 male white police officers and 29,277 State cases. The analysis included SMORS and it was identified that there was an elevated risk of melanoma (SMOR=292; 95% CI 170-503), bladder cancer (SMOR 159; 95% CI 107-414) for firefighters compared to State residents. In comparison with police officers, there was an increase risk in bladder cancer (SMOR=211; 95% CI 107-414) and non-Hodgkin's Lymphoma (SMOR=32; 95% CI 119-898). A number of difficulties with the study were identified by the researchers including the potential for underreporting of cancers.	++	The analysis identified an elevated incidence of melanoma (SMOR=292; 170-503) for firefighters, compared to State residents. An analysis by age group showed the middle group to have a statistically significant incidence, which was higher than that for either of the other two sub-cohorts: 18-54: SMOR=55 (16-196); 55-74: 513 (150-1750); 75+: SMOR=110, 13-934.

3.2.12 Breast Cancer

Although more usually considered in females, male breast cancer is of some concern and was studied by a few papers in relation to firefighters. The mortality and morbidity studies of Ma and co-workers (2005 and 2006) included this cancer amongst both males and females and two others (Kang *et al*, 2009 and Demers *et al*, 1994) considered breast cancer morbidity amongst male firefighters.

Figure 10 shows the risk estimates reported for this type of cancer. The risk estimate from the mortality study of Ma and colleagues (2005) stands out as showing a very high risk of mortality (SMR=7.41, 1.99-19.0) which, despite a very broad confidence interval due to the relatively low number of deaths (4), still attained statistical significance. This was not mirrored in the morbidity study on the same cohort (Ma *et al*, 2006, SIR=0.51, 0.06-1.84) where only two cases were registered. However, this could feasibly reflect a poor detection rate, with few cases being identified early enough. Interestingly, the figures for female firefighters from the same two studies show mortality rates below expectations (SMR=0.51, 0.01-2.82) and morbidity rates almost in line with expectations (SIR=0.96, 0.46-1.76).

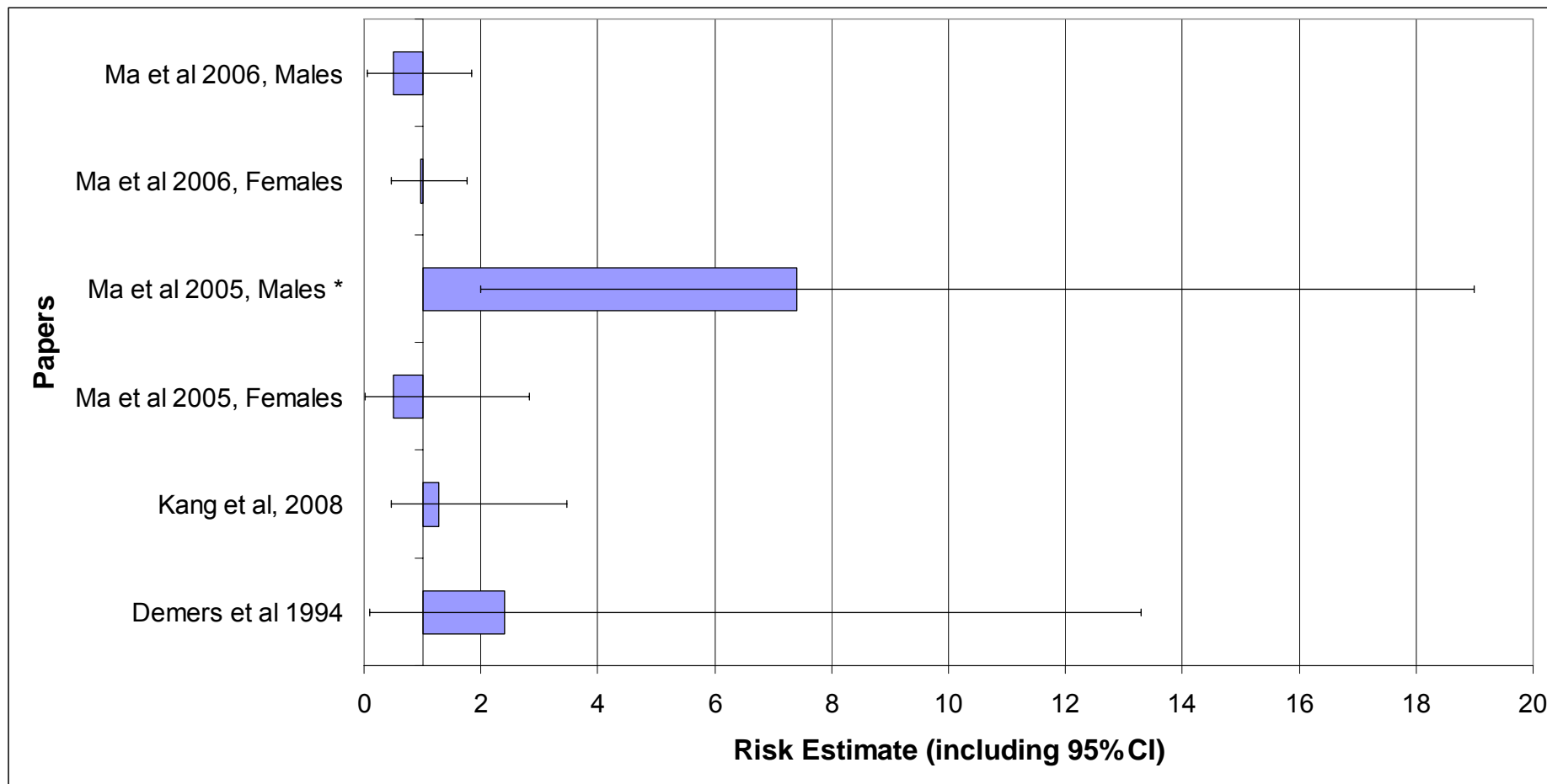
Demers *et al* (1994) did however report an elevated risk of morbidity with an SIR of 2.4 (0.3-2.9) although clearly not significant, being based on only one case. This form of cancer did not feature in the mortality study of the same cohort (Demers *et al*, 1992a).

Clearly, although the elevated risk of mortality from breast cancer within the Florida cohort is interesting, there is no consistent evidence of any generally elevated risk amongst firefighters although, given the limited evidence, it would be difficult to assign a specific risk estimate to this.

Of the four papers, three presented an estimate of person-years of follow-up (or equivalent). These totalled 945,688 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years. The female cohorts from the same two studies had estimates of 17,548 and 18,843 person-years respectively

No review papers considered this form of cancer.

Table 10 summarises the evidence relating to firefighting and breast cancer.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 10: Comparisons of relative risks (with 95% confidence intervals) for breast cancer, derived from published studies

Table 10. Evidence relating to Fire Fighting and Breast Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Male breast cancer had an SIR=2.4 (0.1-13.3) based on 1 death. This form of cancer did not feature in the analysis by duration of exposed employment or by years since first employment.
Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Male breast cancer yielded an SMOR=1.28 (0.47-3.45) based on 4 registrations. All of the cancers apparently occurred in one sub-cohort in the age-stratified data: 55-74: SMOR=0.42 (0.04-4.72).
Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	Four deaths from breast cancer amongst the male cohort yielded an SMR=7.41 (1.99-19.0). One death from this cancer was recorded amongst the female cohort (SMR=0.51, 0.01-2.82). A subsidiary analysis of three deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) has an apparent proof-reading error as the quoted SMR=6.98 but the 95% confidence interval is 0.65-1.68, suggesting an SMOR=0.98.

Ma <i>et al.</i> , 2006	<p>A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.</p>	++	<p>Two registered cases of breast cancer amongst the male cohort yielded a SIR=0.51 (0.06-1.84). Ten cases of this cancer were recorded amongst the female cohort, yielding an SIR=0.96 (0.46-1.76).</p>
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3.2.13 Cervical Cancer

The vast majority of firefighters in the UK, as elsewhere, are male, although there are an increasing number of female firefighters in some brigades and the proportion is likely to increase. Only one paper (Ma *et al*, 2006) had a large enough group of female firefighters to form a viable sub-cohort for analysis. There were 15 incident cases of cervical cancer within this sub-cohort, from an estimated 18,843 person-years of follow-up. This equated to a statistically significant positive association (SIR=5.24, 2.93-8.65). Although clearly the results from a single study must be treated with caution and clearly, there can be many potential factors to account for this, other than occupation, the size of this finding at least suggests a clear need for vigilance amongst the growing numbers of female firefighters in the UK.

3.2.14 Prostate Cancer

A total of 17 papers were identified which presented primary data relating to prostate cancer in firefighters, together with three review papers. Figure 11 shows the risk estimates and confidence intervals around those estimates, derived from those papers. Two estimates are presented for one paper (Ma *et al*, 1998) where data from separate white and black cohorts were reported. From Figure 11 it can clearly be seen that the majority of papers reported a slight excess although, in two papers, estimates in excess of 2 were reported (Grimes *et al*, 1991, RR=2.61, 1.38-4.97; Giles *et al*, SIR=2.09, 0.67-4.88). The estimates from the Grimes *et al* paper, the two from Ma *et al* (1998), and those from Demers *et al* (1994) and Bates (2007) were significantly elevated. In contrast, the studies by Beaumont *et al* (1991) amongst San Francisco firefighters, and that of Donnan (1996) in a cohort of UK firefighters, both reported significantly reduced levels of mortality.

Of the 17 papers, 11 presented an estimate of person-years of follow-up (or equivalent). These totalled 1,665,249 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

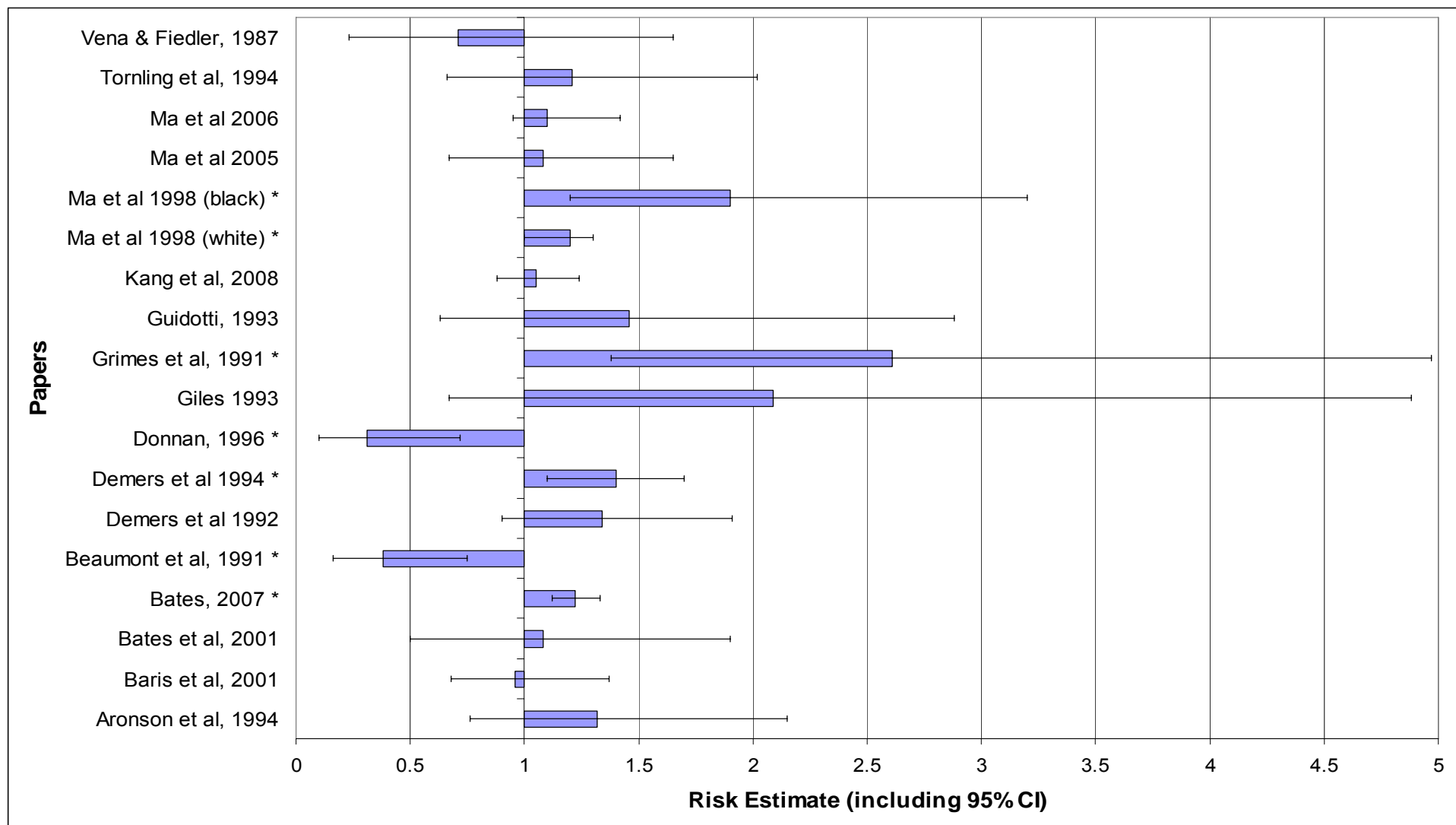
The three review papers identified were those by Golden *et al* (1995); LeMasters *et al* (2006) and Straif *et al* (2007). Golden and co-workers summarise their findings by stating that a 30-50% increase in risk was consistently found in the majority of studies. However, as in the current review, the majority of those increases were not significant. The authors included the study by Beaumont *et al* (1991) which reported a significantly decreased risk.

LeMasters and co-workers applied their more systematic, mathematical approach to summing the risks. The authors concluded that there was a significant elevated risk, with a summary risk estimate of 1.28. Although Le Masters *et al* (2006) included the mortality study by Ma and co-workers (2005) it did not include the subsequent morbidity study (2006) or the papers by Kang *et al* (2008) and Bates (2007), both of which demonstrated excesses (non-significant) but both with risk estimates lower than their summed risk estimate. It did however include the combined firefighter/police cohort study (Demers, *et al*, 1992b) which showed a significantly elevated incidence (SIR=1.37, 1.11-1.69) although this was not markedly dissimilar to the findings of Demers *et al*, (1994) which were excluded. Importantly, it did not include the UK-based study of Donnan (1996) with its significantly reduced risk of prostate cancer.

Straif *et al* (2007) will obviously not have included the paper by Kang and co-workers, but probably did include that by Ma *et al* (2006). It is not known whether or not the report by Donnan (1996) was taken into account although this study has not been reported in the peer-reviewed literature and proved quite difficult to obtain, so the probability is that it was not. The authors derived the remarkably similar average relative risk to that of LeMasters and colleagues of 1.3 (based on data showing increased risks in 18 of 21 studies). Clearly, there would appear to be a strong consensus for this relatively modest increased risk although this is undermined to some extent by the failure to include the study by Donnan (1996) which would undoubtedly reduce any risk estimate below 1.3, and some uncertainty remains regarding the statistical robustness of any current estimate.

As an additional note, although only reflected in one study, the increased prevalence amongst black firefighters over their white counterparts in the study by Ma *et al* (1998) is worth noting. The ethnic mix denoted by the term 'black' is not known but, with gradually increasing numbers of ethnic minorities amongst UK Fire Services, any increased susceptibility to adverse effects within those minorities will be of ongoing concern. Clearly however, no specific statement can be made at present given the limited data available.

Table 11 summarises the evidence relating to firefighting and prostate cancer.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 11: Comparisons of relative risks (with 95% confidence intervals) for prostate cancer, derived from published studies

Table 11. Evidence relating to Fire Fighting and Prostate Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were 16 deaths attributed to cancer of the prostate (ICD 9, 185) in the cohort, yielding a non-significant SMR of 132 (76-215). Further analysis by years since first employment, as a surrogate for exposure showed no significant trend for any increased mortality risk: <20 years: 0 (0-1604); 20-29 years: 244 (30-881); >=30 years: 127 (69-213). An analysis by years of employment also showed no trend: <15 years: 161 (4-899); 15-29 years: 243 (79-566); >=30 years: 97 (44-184). Finally, an analysis of deaths by age showed no significant risk amongst either sub-cohort: <60 years: SMR=153 (19-552); >=60 years 130 (71-218).

Baris <i>et al.</i> , 2001	<p>Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations.</p>	++	<p>31 deaths attributed to cancer of the prostate (ICD 9, 185) yielding a non-significant SMR of 0.96 (0.68-1.37). In the analysis of duration of employment as a surrogate for exposure there were indications of a higher risk amongst those employed for the shortest period: (≤ 9 years, SMR=2.36 (1.42-3.91); 10-19 years, SMR=0.47, (0.19-1.12); ≥ 20 years, SMR=0.72; 0.40-1.31). As an alternative measure of exposure, those who were in ladder companies were more likely to die from prostate cancer although no risk estimates were statistically significant. (engine company: SMR=0.96, (0.56-1.65); ladder company: SMR=1.51 (0.57-4.04); both ladder and engine companies: SMR=0.66, (0.36-1.23)). The analysis of the data by hire year offered no realinsight into any trend: (pre-1935: SMR=0.75 (0.43-1.33); 1935-1944: SMR=1.36, (0.81-2.30); post 1944: SMR=0.83, (0.34-1.98)).</p>
Bates <i>et al.</i> , 2001	<p>This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).</p>	+	<p>In the whole-period analysis (1977-1996) cancer of the prostate had a SIR=1.08 (0.5-1.9) based upon 11 cancers. Over the shorter period for which there was considered to be more complete data (1990-1996), there were nine such cancers yielding a very similar SIR=1.09 (0.5-2.1).</p> <p>Analysis of the data by years of paid service only, demonstrated an apparent trend for a reducing incidence although none of the SIRs were statistically significant: 0-10 years: SIR=1.46, 0.3-4.3; 11-20 years: SIR=0.60, 0.0-3.3; >20 years: SIR=0.29, 0.0-1.6. Paid and volunteer firefighters combined had an elevated but non-significant incidence for the middle sub-cohort.</p> <p>No results were reported for mortality from prostate cancer.</p>

Bates 2007	Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).	+	The occupation of fire-fighting was significantly associated with prostate cancer (Odds Ratio=1.22, 1.12–1.33), based on 1,144 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988–1995 and 1996–2003. Both showed a significant risk with the older registrants OR=1.46 (1.12–1.91) and younger registrants OR=1.55 (1.28–1.88) based on 89 and 214 cases respectively.
Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; 0.07–0.68); diabetes mellitus (OR 0.36; 0.14–0.75); diseases of the heart (OR 0.89; 0.81–0.97); diseases of respiratory system (OR 0.63; 0.47–0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85–0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27–1.92); cirrhosis and other liver disease (OR 2.27; 1.73–2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04–1.55); and oesophagus (OR 2.04; 1.05–3.57) and reduced risks of cancers of the genital organs (OR 0.40; 0.18–0.77) and the prostate (OR 0.38; 0.16–0.75). Prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for cancer of the prostate was significantly lower than expected: RR=0.38, 0.16–0.75), based on eight deaths. Exposure-related data was not included for this cancer.
Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 1.3–3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 1.2–8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 1.1–3.6) and leukaemia (SMR=2.6; 1.0–5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Prostate cancer had an SMR=1.34 (0.90–1.91) based on 30 deaths. An analysis by duration of exposed employment showed no particular trend: <10years: SMR=2.42 (0.5–7.1); 10–19 years: SMR=1.12 (0.1–4.1); 20–29 years: SMR=1.23 (0.7–2.1); > 30 years: SMR=1.36 (0.7–2.4). A similar analysis by years since first employment showed all the cases falling in the oldest sub-cohort, yielding a statistically significant value for 30+ years: SIR=1.42 (1.0–2.0). Finally, the authors analysed the data by age at risk, which showed a trend for an increasing risk for prostate cancer with increasing age at risk: 18–39 years old: SMR=0.00 (0.0–1.78); 40–64 years old: SMR=0.86 (0.2–2.2); >65 years old: SMR=1.46 (1.0–2.1).

Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Prostate cancer had a statistically significant SIR=1.4 (1.1-1.7) based on 66 deaths. An analysis by duration of exposed employment showed no particular pattern with an isolated statistically significant outcome for one sub-cohort : <10 years: 1.4, (0.6-2.8); 10-19 years: 1.2 (0.4-2.6); 20-29 years: 1.5 (1.1-2.0); 30+ years: 0.9 (0.3-1.9). A similar analysis by years since first employment suggested a greater risk amongst the oldest sub-cohort: <20 years: SIR=7.4 (0.2-41); 20-29 years: 1.8 (0.6-4.3); SIR=30+ years: SIR=1.3 (1.0-1.7).
Donnan, 1996	This reported the study of mortality and cancer incidence amongst a UK cohort of 5,568 firefighters drawn from five Brigades and compared against statistics for adult males from England and Wales. The cohort was followed for approximately 30 years (1965-1993). With few exceptions, deaths from the various causes studied were significantly lower than expected. This included deaths from all causes: SMR=0.67 (0.62-0.72); all circulatory diseases: SMR=0.70 (0.60-0.80); CHD: SMR=0.72 (0.61-0.85); all cancers: SMR=0.72 (0.60-0.86); and lung cancer: SMR=0.47 (0.32-0.67). Cancer registrations were also generally significantly lower with specific Standardised Registration Ratios (SRR) of: skin cancer: SRR=0.63 (0.39-0.97); lung cancer: SRR=0.24 (0.14-0.40); colon and rectal cancer: SRR=0.56 (0.32-0.93); bladder cancer: SRR=0.72 (0.36-1.26); stomach cancer: SRR=0.42 (0.17-0.88); and prostate cancer: SRR=0.31 (0.10-0.72).	++	Based on 8 registered cases, registrations of prostate cancer SRR=0.31 (0.10-0.78), were significantly lower than the England and Wales statistic. Prostate cancer did not feature in any sub-group analysis reported.
Giles 1993	This paper describes the incidence of cancer between 1980-1989 in a cohort of 2,865 male firefighters employed in Melbourne, Australia between 1917 and 1989. The comparison group was the population of the state of Victoria. A total of 50 cancers were registered amongst the cohort, which did not yield a SIR significantly different from the general population. Ten named groups of cancers were described, none of which gave incidences significantly different from 1.0. There were significantly elevated incidences of "all cancers" and cancers of the colon and rectum amongst the older sub-cohort ≥ 65 years: all cancers: 2.14, (1.32-2.37); colorectal cancers: 3.65, (1.13-7.14). Neither time since start of employment or duration of employment resulted in any incidences significantly different from the comparison population.	++	Five registered cases of prostate cancer gave an SIR=2.09, (0.67-4.88).

Golden <i>et al</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain,; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	States that a 30-50% increase in risk of prostate cancer was consistently found in the majority of studies although the majority of these increases were not significant.
Grimes <i>et al</i> 1991	A twenty year Proportionate Mortality study was conducted with all male firefighters in the City of Honolulu from 1969-1988 who had at least one year of service. This covered 205 deaths. Significant increases in risk of death were found for brain cancer (ICD 9, 191-192) (PMR=3.78, 1.22-11.71); prostate cancer (ICD 9 185) (PMR=2.61, 1.38-4.97); and cirrhosis of the liver (ICD 9 571) (PMR=2.3, 1.21-4.37). It was suggested that the latter could, at least in part, be attributed to an excess of alcohol consumption in this group. A significant decrease in mortality was observed for respiratory diseases (ICD 9 460-519) (PMR=0.37, 0.17-0.81).	+	The PMR for prostate cancer (ICD 9, 185) was statistically significant, based upon 9 deaths: RR=2.61 (1.38-4.97). A subsidiary analysis for firefighters of Caucasian or Hawaiian extraction yielded values of 3.70 (1.71-8.02) and 3.35 (1.07-10.45) based upon six and three deaths respectively.
Guidotti 1993	Cause of death was examined for two cohorts totalling 3,328 firefighters from Edmonton & Calgary (Alberta) in Canada. The firefighters were active from 1927-1987. Data was analysed over the entire cohort; by entry date; for latency as years since entry; and for duration of employment. Mortality from all causes was close to expected (SMR=96, 87-107) as was that for heart disease (SMR=110, 92-131). Statistically significant excesses were observed for: all malignant neoplasms (SMR=127, 102-155); kidney & ureter cancers (SMR=414, 166-853); and mental disorders (SMR=455, 274-711). Only isolated excesses were apparent from any of the latency or exposure-related analyses.	++	Prostate cancer (ICD 9 185) had an SMR=146, (63-288) which was not statistically significant. It did not feature in the breakdown analysis by entry date. A series of latency analyses were reported, broken down by "exposure opportunity" which related generally to the job category in which the individual was employed. An initial all subjects analysis showed the suggestion of a possible trend for an increasing risk of prostate cancer with years of latency, none of which values were statistically significant: <20 years: SMR=0.0; 20-29 years: SMR=259; 30-39 years: SMR=165; 40-49 years: SMR=120; 50+ years SMR=145. In an analysis by exposure index, isolated small numbers of deaths amongst the less exposed sub-cohorts all yielded non-significant SMRs and, even amongst the highest exposed sub-cohort (Index ≥ 10), all SMRs were non-significant: <20 years: SMR=0.0; 20-29 years: SMR=366; 30-39 years: SMR=204; 40-49 years: SMR=136; 50+ years SMR=114.

Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Cancer of the prostate yielded an SMOR=1.05 (0.88-1.24) based on 577 registrations. No trend was apparent in the age-stratified data: 18-54: SMOR=1.14 (0.65-2.00); 55-74: SMOR=1.05 (0.78-1.43); 75+: SMOR=0.91 (0.58-1.43).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The meta-analysis across all forms of study, utilising a total of 13 analyses, yielded what the authors regarded as a probable risk of an association with a significant Summary Risk Estimate of 1.28 (1.15 –1.43) for prostate cancer. This was consistent with the meta-SMR of 1.29, (1.09-1.51 and the heterogeneity of the data was not significant at the 10% level.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, cancer of the prostate had a significant MOR=1.2 (1.0-1.3), based on 189 deaths. For black firefighters 16 deaths yielded an MOR=1.9 (1.2-3.2) which was also statistically significant.

Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	21 deaths from prostate cancer amongst the male cohort yielded an SMR=1.08 (0.67-1.65). A subsidiary analysis of 19 deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave a very similar outcome with SMR=1.07 (0.3-1.45).
Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	209 registered cases of prostate cancer amongst the male cohort yielded a SIR=1.10 (0.95-1.42) which narrowly failed to attain statistical significance.
Straif <i>et al.</i> , 2007	Update of a previous meta-analysis by IARC. Identified that testicular cancer showed increased risk in firefighters (average RR 1.5), prostate cancer was also increased with an average RR of 1.3. Non-Hodgkin's Lymphoma was increased with an average RR of 1.2. Study stated on the basis of limited evidence that exposure as a firefighter is possible carcinogenic to humans (Group 2B)		The authors identified increased risks of prostate cancer in 18 of 21 studies.

Tornling <i>et al.</i> 1994	et	An investigation of cancer incidence and mortality rates in Swedish firefighters. All male firefighters employed for at least one year in the City of Stockholm between 1931 and 1981 were traced. This resulted in 1,153 individuals but a further group were already deceased so the total sample size was 1,116 males. Exposure measures were also made using a 10% sample of fire reports which was developed into an exposure index for each calendar year and each fire station. Standardised mortality ratios were calculated. The analysis identified that overall mortality was lower than expected (SMR=82; 95% CI 72-91). The cancer incidence was equal to expected but increased stomach cancer was observed (SMR=192; CI 114-304) and brain cancer (SMR 496; 95% CI 135-270).	++	14 deaths from prostate cancer resulted in an SMR=121 (66-202). There was a similar morbidity risk (SIR=114, 76-165). Further analyses of prostate cancer incidence were not reported.
Vena Fiedler, 1987	and	A mortality study of municipal workers which all full-time employees of Buffalo USA between 1950 and 1979 for a minimum of 5 years. Individuals who had worked at least one year as a firefighter were included. At data collection this was 1,867 white male firefighters including 890 currently employed, 740 retirees, 65 who had resigned and 172 who died in service. The analysis identified that firefighters had significantly more benign neoplasms (SMR=4.17; 95% CI 1.34-9.73), malignant neoplasms including colon cancer (SMR=1.83; 95% CI 1.05-2.97), and bladder cancer (SMR=2.86; 95% CI 1.30-5.40).	++	Five deaths from prostate cancer amongst the cohort yielded an SMR=0.71 (0.23-1.65). Cancer of the prostate did not feature in subsidiary analyses of firefighters with estimates of exposure.

3.2.15 Testicular Cancer

Testicular cancer has recently been the subject of an IIAC review, culminating in the publication of a position paper (IIAC, 2008). This outlined concerns regarding a possible association between testicular cancer and the occupation of firefighting, which was apparently precipitated by a meta-analysis LeMasters *et al.*, 2006 of cancer in firefighters suggesting a summary Risk Estimate of 2.02 (1.30-3.13) for testicular cancer.

The position paper refers to initial concerns on this topic prompted by a report of a cluster of such cases in New Zealand (Bates *et al.*, 1995). A follow-up to this (Bates *et al.*, 2001) again found an elevated risk although not as marked as that related to the cluster. The position paper then cites three other papers. Stang *et al.* (2003) found a considerably elevated odds ratio (4.3) which was not however statistically significant. (Bates, 2007) found an odds ratio (1.54 with the exclusion of other cancers) which was lower but statistically significant and Ma *et al.* (2006) reported a similar odds ratio to the previous paper (1.6) again statistically significant. The meta-analysis (Le Masters *et al.*, 2006) utilised two of these papers (Bates *et al.*, 2001 and (Stang *et al.*, 2003) together with two others by Aronson *et al.*, (1994) and Giles *et al.*, (1993) in formulating its estimate.

The IIAC position paper indicated that the meta-analysis excluded a considerable number of other papers, referred to in the bibliographies of the papers cited, which apparently showed no clear association between deaths from testicular cancer and firefighting, including a negative case-control study (Pearce *et al.*, 1987).

Interpretation of the apparent failure on the part of a number of these studies to identify any risk of testicular cancer should be treated with caution. Thus, as stated earlier, it is unlikely that the study by Pearce and co-workers had sufficient sensitivity to have identified testicular cancer.

Similarly, Beaumont *et al.*, 1991 cited in two of the four papers, reported 'genital organs' as a composite category and, of the nine cases identified, eight had prostate cancer (the ninth was not specified).

Huyghe *et al.*, (2003) has reported that the incidence of testicular cancer is increasing, leading to the expectation that studies encompassing older populations might be less likely to identify testicular cancer. Some countries (e.g. Denmark) have seen a three-fold increase in incidence from 1944-1988. It is not known whether this is increased reporting; improved recording; or a genuine increase in incidence. However, it should be noted that this is incidence, not mortality, and other papers have indicated that, whilst incidence is rising, mortality has remained relatively stable.

Eight papers were selected for the present review, having identified a risk estimate for testicular cancer. Figure 12 presents the main group findings from these papers. Most of these (six) were morbidity studies with two (Aronson *et al.*, 1994; Ma *et al.*, 1998) reporting mortality. The latter paper was the only one of the eight to report a negative association. However, this was based on only one death and the authors were unable to assign a confidence interval to this estimate. Care should be taken in attributing too much significance to this finding. The other mortality studies examined for this review did not identify testicular cancer.

In some instances, the authors had pre-selected the cancers for study (e.g. Sama *et al.*, 1990, excluding testicular cancer. Others only reported a selective proportion of

specified cancers (e.g. Tornling *et al*, 1994, only reported specific causes for 79 out of 93 deaths from malignant tumours). The basis of this selection is not given.

From Figure 12, the very high value of 8.2 is that reported in what has become regarded as the 'original' cluster analysis (Bates *et al.*, 1995) and has not been reproduced since, even in studies of the same (New Zealand) population (Bates *et al*, 2001). In addition to this first paper, three more recent papers (Bates, 1007; Kang *et al*, 2008; and Ma *et al*, 2006) were not covered by the Le Masters review and, with all three identifying positive associations (two of them statistically significant), this would undoubtedly have reinforced the conclusion of that meta-analysis.

The mortality study of Ma and co-workers (1998) was not utilised in the meta-analysis. This was clearly because, as stated above, with only one mortality, the original paper did not provide a confidence interval around their risk estimate and would therefore have not met the inclusion criteria for the meta-analysis for this form of cancer (although it was used for others).

One further paper Firth *et al.*, 1996 failed to identify a significant excess of testicular cancer incidence amongst firefighters in New Zealand. However, this paper was restricted to occupations with in excess of 400 cases (all cancers) or to those occupations and cancers where the computed SIR was statistically significant (lower bound >100) and where there were more than five reported cases.

Of the eight papers, only three presented an estimate of person-years of follow-up (or equivalent). These totalled 590,009 person-years.

Of the other reviews identified for the present paper, those by Golden *et al* (1995) and Straif *et al.*, (2007) covered testicular cancer. Howe and Burch (1990) preselected a list of cancers for inclusion which did not include testicular cancer, apparently reflecting a lack of concern at that time; Haas *et al* (2003) only considered mortality studies which included time-dependent data; and Youakim (2006) again restricted the review to a limited number of specified forms of cancer, selected on the basis of having been recognised by Canadian provincial governments as occupational diseases amongst firefighters.

Golden *et al* (1995) only identified two papers and restricted their conclusions to the recommendation that testicular cancer should be assessed in future studies of firefighters. It therefore adds little to the current debate.

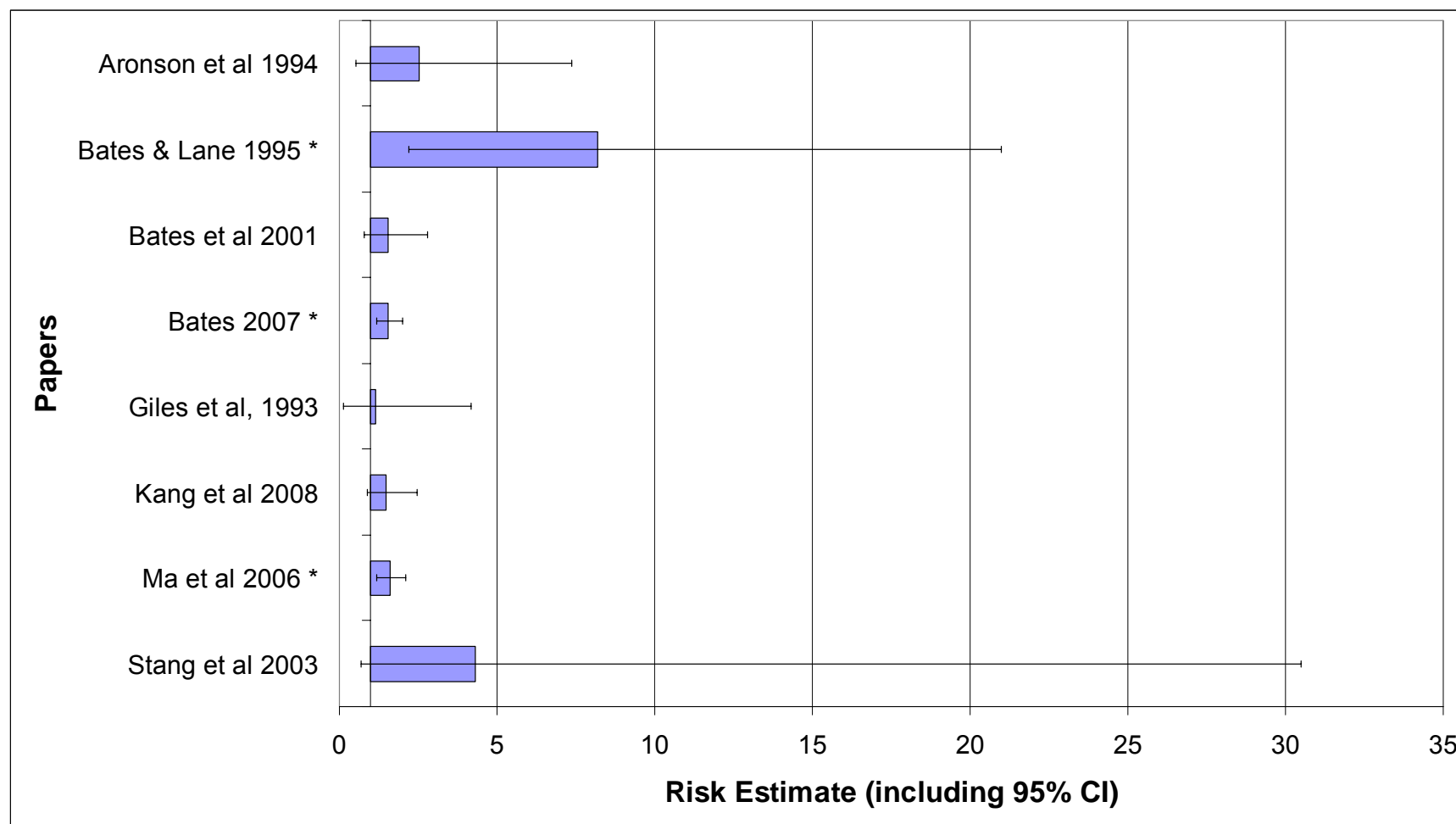
The IARC summary review, reported by Straif *et al* (2007), reportedly updated the meta-analysis of LeMasters *et al* (2006). Although the summary does not specify the studies added, it notes that "all six studies showed increased risks" giving an average relative risk of 1.5.

As stated above, the recent material identified which was not covered by the review by LeMasters and co-workers tends to reinforce the view that there is a positive association between the incidence of testicular cancer and the occupation of firefighting. However, the lower risk estimates from these studies suggests that the value of 2.02 derived by LeMasters and colleagues was probably an overestimate and a value of less than 2.0 would seem more appropriate. This is consistent with the summary review of Straif *et al* (2007) which indicates an average relative risk across six studies of 1.5.

As with other forms of cancer, the existence of a positive association is not necessarily indicative of a causal relationship and a number of the papers which

have identified such an association have not identified plausible mechanisms to justify such a conclusion. It is known that, in some parts of the UK Fire Service at least, there has been an increased awareness of testicular cancer for some years. Although none of the published studies relate to the UK, if the same awareness is prevalent in other countries, it is at least plausible that the apparent excess is due (at least in part) to that enhanced awareness and consequent reporting. Clearly, as was recognised by the IIAC position paper, this is a form of cancer which should continue to be subject to scrutiny, particularly given the evidence for a trend towards increased incidence.

Table 12 presents a summary of the evidence relating to firefighting and testicular cancer.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 12: Comparisons of relative risks (with 95% confidence intervals) for testicular cancer, derived from published studies

Table 12. Evidence relating to Fire Fighting and Testicular Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	<p>There were 3 deaths attributed to testicular cancer (ICD 9, 186) in the cohort, yielding a non-significant SMR of 252 (52-737).</p> <p>Further analysis by years since first employment, as a surrogate for exposure showed a higher (non-significant) mortality amongst those employed for a shorter period: <20 years: SMR=326 (67-953); 20-29 years: SMR=0 (0-2459); >=30 years: SMR=0 (0-3074). An analysis by years of employment also showed a similar trend: <15 years: SMR=366 (75-1069); 15-29 years: SMR=0 (0-1419); >=30 years: SMR=0 (0-3689). Finally, an analysis of deaths by age showed an increased (non-significant) risk amongst the younger sub-cohort: <60 years: SMR=275 (57-804); >=60 years SMR=0 (0-4099).</p>

Bates and Lane, 1995	The authors reported an investigation of an apparent cluster of cases of testicular cancer amongst firefighters in Wellington, New Zealand, based on data from the NZ cancer registry. Four cases were investigated of which only two appeared in their registry data. Relative risks were calculated for 3 study populations: 217 firefighters who participated in a major chemical fire (1984-1989, 2 cases, SIR=16.7, 1.9-60); 350 firefighters from whom the 217 were drawn (1984-1989, 3 cases, SIR=15.5, 3.1-45) and a presumed complement of 350 across the period 1980-1991 (from which there were 4 cases, SIR=8.2, 2.2-21)	+	See study details.
Bates <i>et al</i> , 2001	This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).	+	<p>In the whole-period analysis (1977-1996) testicular cancer had an SIR=1.55 (0.8-2.8) based upon 11 cancers. Over the shorter period for which there was considered to be more complete data (1990-1996), there were eight such cancers yielding a higher, significant incidence: SIR=2.97 (1.3-5.9).</p> <p>Analysis of the data by years of paid service only, demonstrated an apparent trend for an increased incidence although only one of the SIRs were statistically significant: 0-10 years: SIR=1.55, 0.3-4.5; 11-20 years: SIR=3.51, 1.0-9.0; >20 years: SIR=4.14, 0.5-14.9. A similar but smaller trend was observed amongst paid and volunteer firefighters combined.</p> <p>No deaths were reported from testicular cancer.</p>

Bates 2007	Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).	+	The occupation of fire-fighting was significantly associated with testicular cancer (Odds Ratio=1.54, 1.18–2.12), based on 70 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988-1995 and 1996-2003. Both showed an excess, although only that for the older registrants was significant: 1988-1995: OR=1.92 (1.32-2.80); 1996-2003: OR=1.29 (0.87-1.92).
Giles 1993	This paper describes the incidence of cancer between 1980-1989 in a cohort of 2,865 male firefighters employed in Melbourne, Australia between 1917 and 1989. The comparison group was the population of the state of Victoria. A total of 50 cancers were registered amongst the cohort, which did not yield a SIR significantly different from the general population. Ten named groups of cancers were described, none of which gave incidences significantly different from 1.0. There were significantly elevated incidences of “all cancers” and cancers of the colon and rectum amongst the older sub-cohort ≥ 65 years: all cancers: 2.14, (1.32-2.37); colorectal cancers: 3.65, (1.13-7.14). Neither time since start of employment or duration of employment resulted in any incidences significantly different from the comparison population.	++	Two registered cases of testicular cancer gave an SIR=1.15, (0.13-4.17).

Golden <i>et al</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain;; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	The authors only identified two papers relating to testicular cancer and firefighting. On the basis of these they recommended that this form of cancer should be examined more closely in future studies.
Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Testicular cancer yielded an SMOR=1.48 (0.88-2.48) based on 25 registrations. No trend was apparent in the age-stratified data although there were no cases of testicular cancer in the oldest sub-cohort: 18-54: SMOR=1.21 (0.60-2.45); 55-74: SMOR=1.40 (0.09-23.08).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The authors indicated a possible association between testicular cancer and firefighting. The meta-analysis across all forms of study, utilising a total of four analyses, yielded a significant Summary Risk Estimate of 2.02 (1.30 –3.13) for testicular cancer. This was slightly higher than the meta-SMR of 1.83, (1.13-2.79) and the heterogeneity of the data was not significant at the 10% level.

Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	One registered case of testicular cancer amongst the male cohort yielded a MOR=0.60.
Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	54 registered cases of testicular cancer amongst the male cohort yielded a significantly elevated risk estimate: SIR=1.60, (1.20-2.09).
Stang <i>et al.</i> , 2003	Recruited those with diagnosis of testicular cancer in 5 regions of Germany (78% response rate) with 2 or 4 controls per case (more for older patients) recruited from same areas (57% response rate). 3 controls (0.4%) and 4 cases (1.5%) yielded an OR of 4.3 (0.7-30.5). Authors account for small case numbers as paper was based on an opportunistic study selecting firefighters from existing cohort.	+	Those who had ever worked as a firefighter had a risk estimate for testicular cancer of 4.3 (0.7-30.5). In an analysis based on years of employment the Odds Ratios remained elevated but were again not significant.

Straif <i>et al.</i> , 2007	Update of a previous meta-analysis by IARC. Identified that testicular cancer showed increased risk in firefighters (average RR 1.5), prostate cancer was also increased with an average RR of 1.3. Non-Hodgkin's Lymphoma was increased with an average RR of 1.2. Study stated on the basis of limited evidence that exposure as a firefighter is possible carcinogenic to humans (Group 2B)	++	Identified that testicular cancer showed increased risk in firefighters (average RR 1.5).
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3.2.16 Bladder Cancer

Data from 16 primary studies was identified for comparison purposes, together with four reviews. The main findings from the primary studies are presented in Figure 13. Not shown are sub-cohort analysis of female firefighters (Ma *et al* 2006) and black firefighters (Ma *et al* 1998). In each instance, the occurrence of a single case in that cohort yielded apparently elevated risks, although these would clearly not provide a reliable estimate (as illustrated by the risk estimate from Ma *et al*, 2006 for female firefighters which yielded a SIR of 10.00 but a confidence interval of 0.13-33.60).

The two studies of Vena and Fiedler (1987) (SMR=2.86, 1.30-5.40) and Guidotti (1993) (SMR=316, 90-810) clearly stand out in suggesting a considerable excess (with that for the former paper statistically significant). However, when balanced against the weight of other studies these clearly do not indicate a consistent effect. Many of these studies derive risk estimates from very small numbers of cases (e.g. Guidotti, 1993 had four cases and Demers *et al*, 1992a had only two), which presumably accounts for the variation in risk estimates and the large confidence intervals surrounding them.

Of the 16 papers, nine presented an estimate of person-years of follow-up (or equivalent). These totalled 1,619,174 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

Golden *et al* (1995) identified eight different studies, from which they derived eleven comparisons (including three where a police cohort was used to calculate relative risk). Two of the main comparisons (Vena and Fiedler, 1987; and Sama *et al*, 1990) yielded significant excesses, balanced to some extent by the significant reduction in risk identified by Demers *et al*, (1992a) (SMR=0.23, 0.03-0.83). The authors observed that, as with the studies presented in figure 13, the majority of studies showed an excess.

Guidotti (1995) listed 13 risk estimates for bladder cancer, including three with no confidence interval cited but not including the study reported by Donnan (1996). These estimates were almost equally balanced, with six reporting a risk estimate less than 100, (range 16-316). Despite this, the author concluded that the risk estimate for bladder cancer in firefighters had an approximate magnitude of 200.

Youakim (2006) utilised data from ten mortality studies in deriving summed Risk Ratios of 1.14 (0.96-1.33) for all studies and 1.21 (0.92-1.56) for cohort studies only. Three incidence/morbidity studies yielded a collective summed Risk Ratio of 1.36 (1.01-1.80) but the report by Donnan (1996), which showed a non-significant negative effect (0.72, 0.36-1.26), was not included in this review.

Bladder cancer also featured in the pooled trend analysis calculated by this author, utilising data from just two papers to derive trend volumes based on years of employment (those by Baris *et al*, 2001 and Vena and Fiedler, 1987). Although one sub-cohort (≥ 40 years) demonstrated a significantly elevated risk (5.71, 1.56-14.63) this was actually only derived from data drawn from the latter of these two papers and should therefore be viewed with caution.

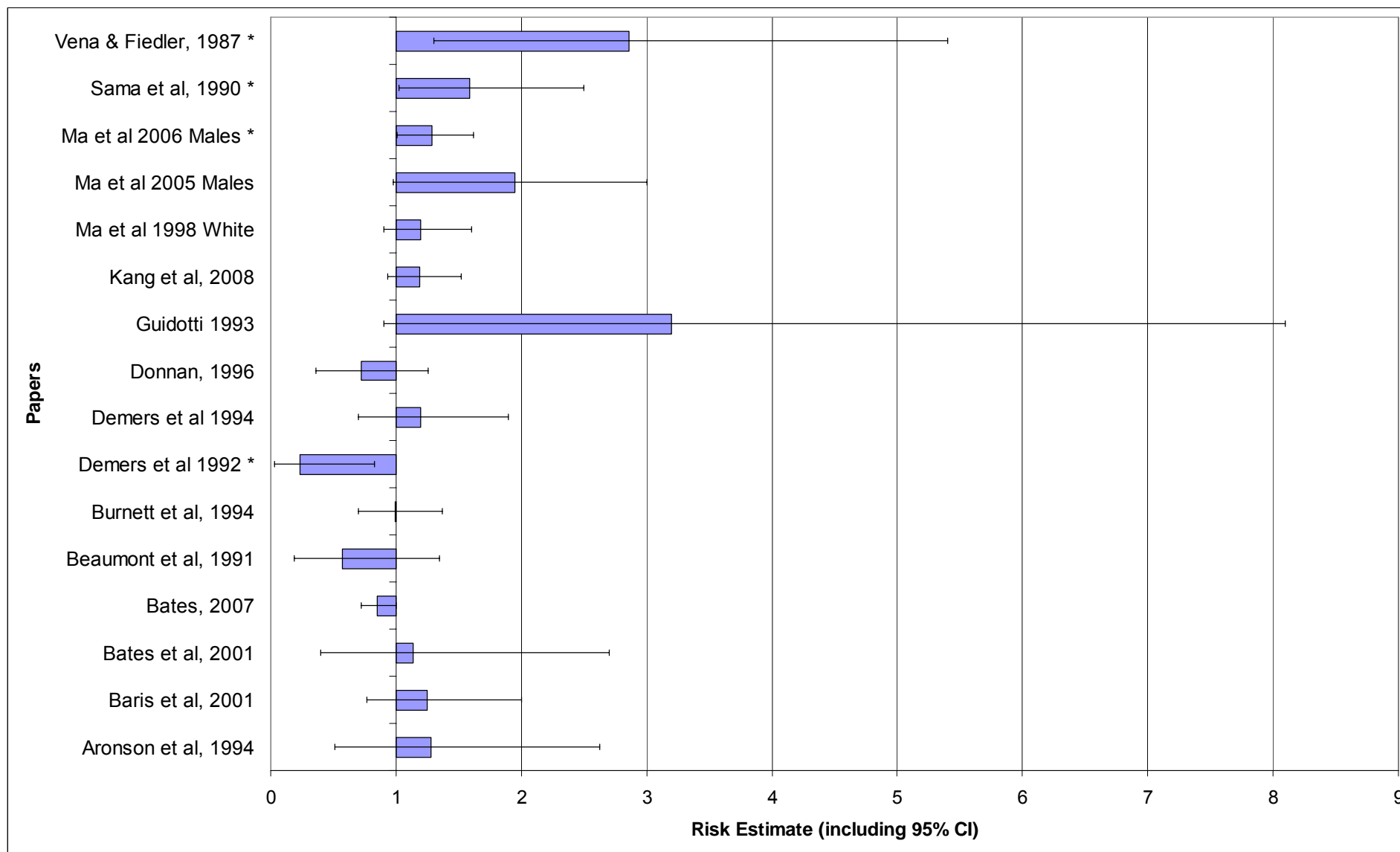
LeMasters *et al* (2006) utilised 11 estimates in determining a Summary Risk Estimate derived from all types of study of 1.20 (0.97-1.48) with the caveat that there was significant heterogeneity between studies. The erroneous inclusion of Demers, *et al*., (1992b) would have reduced this figure slightly as this paper reported a SIR of 1.05

(0.67-1.55) rather than the 1.2 (0.7-1.9) reported by Demers *et al*, 1994. Unlike Youakim (2006) this review did not include data from the mortality study by Ma *et al* (2005), although it was listed in the references, and neither review included the later morbidity study (Ma *et al* 2006) or the more recent papers by Bates, 2007 and Kang *et al* 2008. Both of these recent studies were relatively large with Bates 2007 reporting 174 incident cases and Kang and co-workers 113. In contrast, the Demers *et al*, 1994 morbidity study by Ma and colleagues (2006) yielded 73 cases and the UK cohort (Donnan, 1996) had only 19 registered cases of bladder cancer.

However, their conflicting findings would, to a certain extent, have balanced out, although they would clearly have contributed to the overall heterogeneity.

On balance, the majority of studies still favour a slight excess risk of bladder cancer amongst firefighters, especially given the influence of the two relatively early studies demonstrating a large excess. With two recent morbidity studies showing an excess (Ma *et al*, 2006; Kang *et al* 2008) and one a diminution of risk (Bates 2007) the balance probably favours a slightly increased estimate over that of 1.2 suggested by LeMasters *et al* (2006) (although possibly by as little as 5%). The two relatively recent reviews which calculated summed risk estimates illustrate that any decision as to whether the excess risk is statistically significant is marginal. Clearly however, the increased risk of developing bladder cancer remains well below the requisite criterion for prescription.

Table 13 presents the data relating to firefighting and bladder cancer.



KEY: * indicates risk statistically significantly different from 1.0 (p=0.05)

Figure 13: Comparisons of relative risks (with 95% confidence intervals) for bladder cancer, derived from published studies

Table 13. Evidence relating to Fire Fighting and Bladder Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were seven deaths attributed to bladder cancer (ICD 9, 188) in the cohort, yielding a non-significant SMR of 128 (51-263). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of these deaths.

Baris <i>et al.</i> , 2001	<p>Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations.</p>	++	<p>17 deaths attributed to bladder cancer (ICD 9, 188) yielding a non-significant SMR of 1.25 (0.77-2.00). In the analysis of duration of employment as a surrogate for exposure there were signs that those employed for less time were more likely to have a diagnosis of bladder cancer although none of the effects were significant: (≤ 9 years, SMR=1.36 (0.51-3.61); 10-19 years, SMR=1.48, (0.70-3.09); ≥ 20 years, SMR=1.01; 0.45-2.25). As an alternative measure of exposure, there were indications that those who were in ladder companies (with or without time in an engine company) were more likely to die from bladder cancer, although none of the effects were significant: SMR=0.53, (0.17-1.65); ladder company: SMR=1.81 (0.45-7.23); both ladder and engine companies: SMR=1.70, (0.94-3.07)). There were suggestions that those recruited longer ago were likely to show greater mortality than those recruited more recently: (pre-1935: SMR=1.71 (0.94-3.08); 1935-1944: SMR=1.17, (0.49-2.81); post 1944: SMR=0.35, (0.05-2.43)).</p>
Bates <i>et al.</i> , 2001	<p>This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).</p>	+	<p>In the whole-period analysis (1977-1996) bladder cancer had an SIR=1.14 (0.7-1.8) based upon five cancers. Over the shorter period for which there was considered to be more complete data (1990-1996), there were two such cancers yielding a lower SIR=0.74 (0.1-2.7).</p> <p>Analysis of the data by years of paid service only did not feature this cancer.</p> <p>Two deaths from bladder cancer resulted in an SMR= 2.73, (0.3-9.8).</p>

Bates 2007	Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).	+	Those with an occupation of fire-fighting were significantly less likely to have bladder cancer (Odds Ratio=0.85, 0.72–1.00), based on 174 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988-1995 and 1996-2003. In this analysis the risk of bladder cancer remained depressed, but not significantly so: 1988-1995: OR=0.71 (0.44-1.14); 1996-2003: OR=0.94 (0.63-1.40).
Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Bladder cancer had a significantly depressed SMR=0.23 (0.03-0.97) based on two deaths. This cancer did not feature in any of the analyses for surrogates of exposure.
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Bladder cancer had an SIR=1.2 (0.70-1.9) based on 18 registered cases. An analysis by duration of exposed employment showed no particular pattern: <10 years: 2.2 (0.6-5.6); 10-19 years: 0.9 (0.1-3.4); 20-29 years: 1.0 (0.4-1.8); 30+ years: 1.6 (0.3-4.8). A similar analysis by years since first employment also showed no particular pattern: <20 years: SIR=1.4 (0.0-7.5); 20-29 years: 2.0 (0.5-5.1); SIR=30+ years: SIR=1.0 (0.6-1.8).

Donnan, 1996	This reported the study of mortality and cancer incidence amongst a UK cohort of 5,568 firefighters drawn from five Brigades and compared against statistics for adult males from England and Wales. The cohort was followed for approximately 30 years (1965-1993). With few exceptions, deaths from the various causes studied were significantly lower than expected. This included deaths from all causes: SMR=0.67 (0.62-0.72); all circulatory diseases: SMR=0.70 (0.60-0.80); CHD: SMR=0.72 (0.61-0.85); all cancers: SMR=0.72 (0.60-0.86); and lung cancer: SMR=0.47 (0.32-0.67). Cancer registrations were also generally significantly lower with specific Standardised Registration Ratios (SRR) of: skin cancer: SRR=0.63 (0.39-0.97); lung cancer: SRR=0.24 (0.14-0.40); colon and rectal cancer: SRR=0.56 (0.32-0.93); bladder cancer: SRR=0.72 (0.36-1.26); stomach cancer: SRR=0.42 (0.17-0.88); and prostate cancer: SRR=0.31 (0.10-0.72).	++	Based on 19 registered cases, registrations of bladder cancer SRR=0.72 (0.36-1.26), were not significantly lower than the England and Wales statistic. Bladder cancer did not feature in any sub-group analysis reported.
Golden <i>et al</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain;; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	The authors identified 8 different studies, from which they derived 11 comparisons. On the basis of these, the authors concluded that the majority of studies showed an excess. No summary risk estimate is presented.

Guidotti 1993	Cause of death was examined for two cohorts totalling 3,328 firefighters from Edmonton & Calgary (Alberta) in Canada. The firefighters were active from 1927-1987. Data was analysed over the entire cohort; by entry date; for latency as years since entry; and for duration of employment. Mortality from all causes was close to expected (SMR=96, 87-107) as was that for heart disease (SMR=110, 92-131). Statistically significant excesses were observed for: all malignant neoplasms (SMR=127, 102-155); kidney & ureter cancers (SMR=414, 166-853); and mental disorders (SMR=455, 274-711). Only isolated excesses were apparent from any of the latency or exposure-related analyses.	++	<p>Bladder cancer (ICD 9 188) had a non-significant SMR=316, (86-808). In an analysis by decade of entry, the oldest cohort (<1920) had a significantly elevated risk of bladder cancer (SMR=710). Of the remaining decades, only the 1940s had any deaths recorded, yielding a non-significant SMR=344.</p> <p>A series of latency analyses were reported, broken down by "exposure opportunity" which related generally to the job category in which the individual was employed. An initial all subjects analysis showed deaths in only two of the sub-cohorts (30-39 years: SMR=277, ns); 40-49 years: SMR=1,393, p<0.01). No confidence intervals were given although statistical significance was reported. The deaths were all within the highest exposure group (≥ 10) with 30-39 years (SMR=354, ns); 40-49 years (SMR=1704, p<0.01).</p>
Guidotti, 1995	Reviews studies of mortality in firefighters. Appears to have included all the main studies identified elsewhere but fails to describe process of identifying and selecting papers. Text summarises major findings and table presents SMR (or PMR) values and confidence intervals. Overall summary table presented as the approximate magnitude of any associations as 100, 150 or 200, presumably signifying relative risk (base 100). These are presumably based upon an interpretation of the accumulated evidence but the method of their derivation is not given. Basis of selection for chosen outcomes to address is not given, described as "specific outcomes of interest". Not all outcomes referred to in text are covered in final table. Thus, the text refers to genitourinary cancers (excluding bladder cancer) as "relatively uncommon cancers...and the risk appears to be high, close to or in excess of a doubled relative risk." Only bladder cancer data abstracted in study summaries and overall summary of associations.	-	Presented risk estimates from 13 studies of bladder cancer, 10 of which had confidence intervals, 3 of which were statistically significantly raised. Estimates ranged from 16-316. 6/13 estimates were less than 100. Based on this material the author concluded that "evidence for an association with genitourinary cancers seems strong" and assigned an approximate risk estimate of 200 to this.

Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Bladder cancer yielded an SMOR=1.19 (0.93-1.52) based on 113 registrations. No trend was apparent in the age-stratified data: 18-54: SMOR=1.28 (0.49-3.30); 55-74: SMOR=1.12 (0.49-3.30); 75+: SMOR=01.41 (0.78-2.54).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	An association between work as a firefighter and bladder cancer was considered unlikely. The meta-analysis across all forms of study, utilising a total of 11 analyses, yielded a non-significant Summary Risk Estimate of 1.20 (0.97 –1.48) for bladder cancer. This was similar to the meta-SMR and PMR of 1.24, (0.83-1.49) and the heterogeneity of the data was significant at the 10% level with heterogeneity among the SMR studies.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, bladder cancer had an MOR=1.2 (0.9-1.6), based on 48 deaths. For black firefighters there was 1 death yielding a MOR of 1.3 but no confidence interval was computed.

Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	14 deaths from bladder cancer amongst the male cohort yielded an SMR=1.79 (0.98-3.00). No deaths from this cancer were recorded amongst the female cohort. A subsidiary analysis of 13 deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave a higher and statistically significant SMR=1.95 (1.04-3.33).
Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	73 registered cases of bladder cancer amongst the male cohort yielded a significant SIR=1.29 (1.01-1.62). One cases of this cancer was recorded amongst the female cohort, giving a SIR=10, (0.13-55.6).
Sama <i>et al.</i> , 1990	A study using cancer registry data from Massachusetts in the USA. Samples included 315 male cancer cases between 1982 and 1986; 392 male white police officers and 29,277 State cases. The analysis included SMORS and it was identified that there was an elevated risk of melanoma (SMOR=292; 95% CI 170-503), bladder cancer (SMOR 159; 95% CI 107-414) for firefighters compared to State residents. In comparison with police officers, there was an increase risk in bladder cancer (SMOR=211; 95% CI 107-414) and non-Hodgkin's Lymphoma (SMOR=32; 95% CI 119-898). A number of difficulties with the study were identified by the researchers including the potential for underreporting of cancers.	++	26 deaths from bladder cancer in the cohort gave a significant SMOR=159, (107-414) for firefighters compared to State residents. An age-specific analysis showed a trend for an increasing SMOR with age, although the SMORs were all non-significant: 18-54 years: 125, 26-588; 55-74 years: 219, 99-484; 75+ years: 440, 42-4626.

Vena and Fiedler, 1987	A mortality study of municipal workers which all full-time employees of Buffalo USA between 1950 and 1979 for a minimum of 5 years. Individuals who had worked at least one year as a firefighter were included. At data collection this was 1,867 white male firefighters including 890 currently employed, 740 retirees, 65 who had resigned and 172 who died in service. The analysis identified that firefighters had significantly more benign neoplasms (SMR=4.17; 95% CI 1.34-9.73), malignant neoplasms including colon cancer (SMR=1.83; 95% CI 1.05-2.97), and bladder cancer (SMR=2.86; 95% CI 1.30-5.40).	++	Nine deaths from bladder cancer amongst the cohort yielded a statistically significant SMR=2.86 (1.30-5.40). In an analysis by years worked, cancer of the bladder gave higher incidences amongst the shortest and longest groups with lower levels in intermediate sub-cohorts: 1-9 years: 5.00; 10-19 years: no deaths; 20-29 years: 1.25; 30-39 years: 2.14; 40+ years: 5.71. The final Risk Ratio was statistically significant. An analysis by calendar year of death showed an increase in deaths in the middle sub-cohort which was statistically significant: 1950-1959: 1.56; 1960-1969: 6.36; 1970-1979: 0.67. For those hired prior to 1930 there was a significantly elevated risk (O/E=4.74). No deaths are recorded from more recent sub-cohorts. Finally, longer years of latency gave elevated risk with the final 2 values significant: 30-39: 1.04; 40-49: 4.53; 50+: 6.38.
Youakim, 2006	An analysis of 16 studies to identify risk of cancer among firefighters. The study identified an increase in risk of kidney cancer (sumRR 1.25; 95% CI 1.02-1.43) and non-Hodgkin's Lymphoma (sumRR 1.4; 95% CI 1.20-1.60). Further analysis using a sub-cohort of studies was also made based on duration of employment with 30 years or more as a firefighter had an increased risk for colon cancer (sumRR 1.51; 95% CI 1.05-2.11), kidney cancer (sumRR 36.12; 95% CI 1.70-16.00), brain cancer (sumRR 2.53; 95% CI 1.27-7.07) and leukaemia (sumRR 2.87; 95% CI 1.43-5.14). After 40 years employment risks for mortality from colon cancer were (sumRR 4.71; 95% CI 2.03-9.27), kidney cancer (sumRR 36.2; 95% CI 4.03-120.42) and bladder cancer (sumRR 5.7; 95% CI 1.56-14.33).	++	Data from 10 mortality studies gave a summed RR=1.14 (0.96-1.33). For cohort studies only, the value was 1.21 (0.92-1.56). 3 morbidity studies yielded a significant summed RR=1.36 (1.01-1.80) with the 2 cohort studies giving a lower estimated RR=1.17 (0.74-1.75). Neither mortality or morbidity gave any exposure-related trend, based on 2 studies.

3.2.17 Kidney Cancer

Thirteen studies are presented as part of this review, with some overlap between cohorts. In addition, five reviews addressed this topic. The primary papers, the main results from which are illustrated in Figure 14, show an inconsistent pattern of results with a slight excess of these showing an increased risk (particularly when accounting for the overlap in cohorts between the two papers by (Demers *et al.*, 1992a, Demers *et al.*, 1994)). One negative paper and two positive papers had risk estimates which attained statistical significance, testimony to the uncertainty in this data set. One isolated paper, that of (Guidotti, 1993), had a very high risk estimate with an SMR of 414 (166-853), but this is not supported by the remainder of the studies.

Of the 13 papers, seven presented an estimate of person-years of follow-up (or equivalent). These totalled 1,529,281 person-years.

Golden *et al.* (1995) do not illustrate their findings for kidney cancer, describing the various studies (eight) as not showing consistently elevated risks and citing examples of both high risks e.g., Burnett *et al.*, 1994 and low risks Demers *et al.*, 1992a.

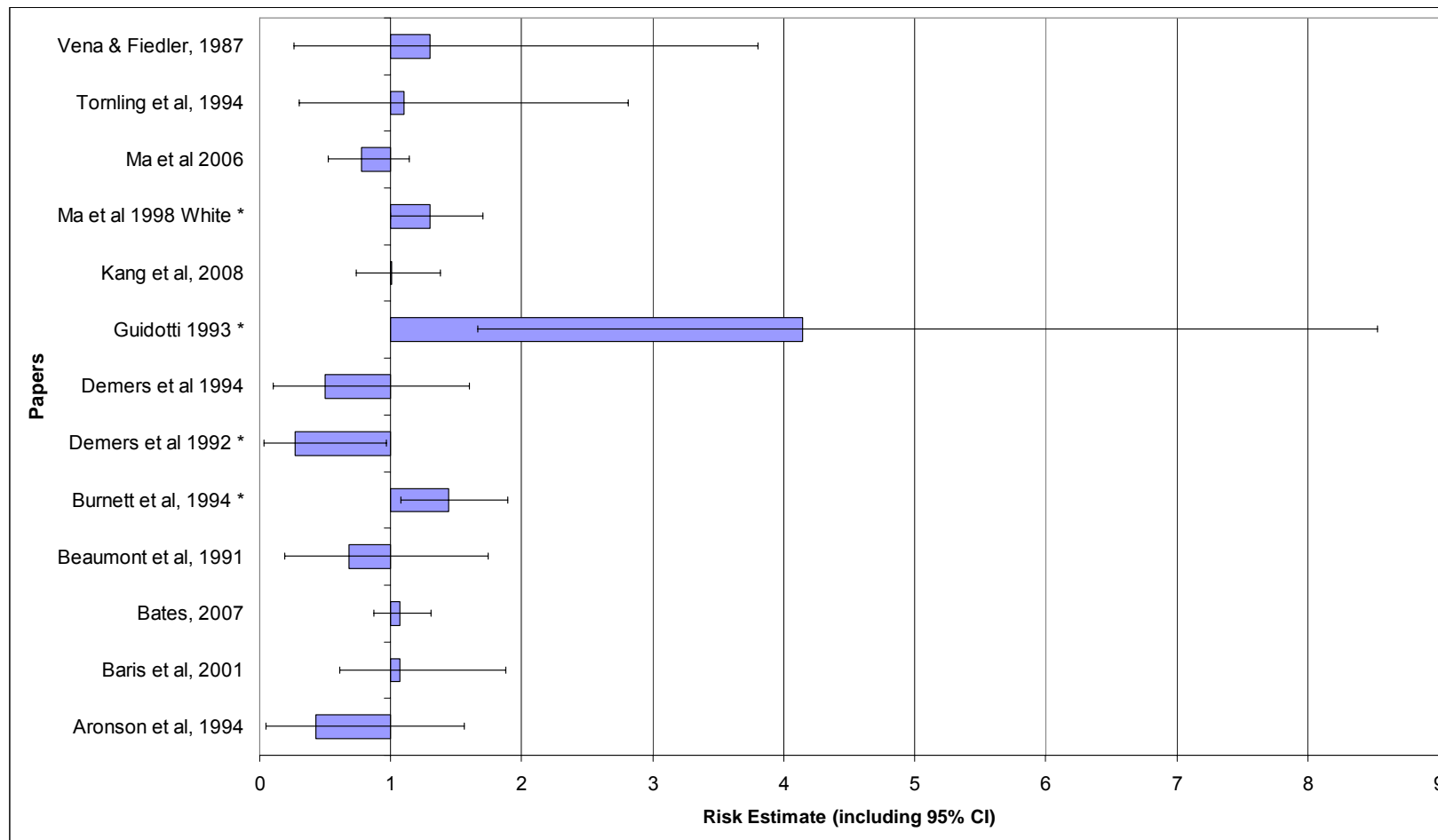
Guidotti, (1995) discussed kidney cancer with other cancers of the genitourinary tract, although the author presented final conclusions separately for bladder cancer and kidney and ureter cancer. Without presenting any detail of individual studies, the author stated that the evidence was strong for an association between firefighters and these cancers, suggesting an approximate risk estimate of 1.5. The author cites the Canadian Industrial Injuries Standards Panel as agreeing to an association subject, it appears, to exposure to occupational carcinogens and with some exclusions.

LeMasters and co-workers (2005) derived data from 12 different studies in deriving a summary risk estimate of 1.07 (0.78-1.46) with significant heterogeneity amongst some groups of studies. As with previous cancers, most of those covered (with the exception of Demers *et al.*, 1992a) are listed in the present review with the exception of the two, more recent studies by Bates (2007) and Kang *et al.* (2008). None of these would be expected to markedly alter the summary risk estimate derived by LeMasters and colleagues. Youakim (2006) included nine mortality studies, yielding a summed risk ratio of 1.22 (1.02-1.43) for all studies and 0.92 (0.64-1.29) for cohort studies. Four incidence or morbidity cohort studies however yielded a summed risk ratio of 0.48 (0.19-0.98). As with LeMasters and co-workers, almost all of the papers included in this present review were included by Youakim who did not however encompass the more recent material from Ma *et al.* (2006); Bates, (2007); and Kang *et al.* (2008). With their conflicting findings these would have had an unpredictable effect on the overall risk estimate, but would probably reduce it, and would certainly increase the uncertainty, probably negating the marginal statistical significance.

One feature of interest in the review paper by Youakim (2008) is the derivation of some estimate of the influence of the duration of employment, based upon two studies (Baris *et al.*, 2001, Guidotti, 1993). There are some indicators from this of a trend towards increased risk of mortality with increasing years of employment beyond ten years. However, these findings rely heavily on the study by Guidotti (1993) which appears to be somewhat of an outlier compared to other reports. In the absence of any supportive evidence therefore, no great import should be attached to these somewhat isolated findings.

It would appear on balance therefore that there is probably a marginal excess risk of kidney cancer amongst firefighters of around 10-20% which is probably not statistically significant.

Table 14 presents the data relating to firefighting and cancer of the kidney.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 14: Comparisons of relative risks (with 95% confidence intervals) for kidney cancer, derived from published studies

Table 14. Evidence relating to Fire Fighting and Kidney Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were 2 deaths attributed to kidney cancer (ICD 9, 189) in the cohort, yielding a non-significant SMR of 43 (5-156). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of these deaths.

Baris *et al.*, 2001 Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations. ++

12 deaths attributed to kidney cancer (ICD 9, 189) yielding a non-significant SMR of 1.07 (0.61-1.88). In the analysis of duration of employment as a surrogate for exposure there was an excess of cases in the longest serving sub-cohort which was statistically significant: (≤ 9 years, SMR=0.72 (0.18-2.87); 10-19 years, no deaths; ≥ 20 years, SMR=2.20, 1.18-4.08). The alternative measure of exposure using company type did not yield any particular trend, and none of the SMRs were significant: (engine company: SMR=1.37, (0.62-3.05); ladder company: no deaths; both ladder and engine companies: SMR=1.05, (0.47-2.34)). In the analysis by year of recruitment, those recruited in the middle cohort had a significantly elevated risk of cancer of the kidney: (pre-1935: SMR=0.57 (0.14-2.29); 1935-1944: SMR=2.11, (1.06-4.24); post 1944: SMR=0.50, (0.12-2.01)).

Bates 2007	Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).	+	The occupation of fire-fighting was not significantly associated with cancer of the kidneys (Odds Ratio=1.07, 0.87–1.31), based on 101 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988-1995 and 1996-2003. This yielded dichotomous results with the older registrants showing an excess OR=1.47 (0.96-2.24) and younger registrants fewer cases than expected OR=0.87 (0.57-1.35) although neither of these were significant.
Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for cancer of the kidneys was reduced, but not significantly (0.68, 0.19-1.74), based on 4 deaths. Exposure-related data was not presented for this cancer.

Burnett <i>et al.</i> , 1994	Assessment of mortality rates for firefighters using information from 27 USA states between 1984-1990. 5,744 deaths in white male firefighters were reviewed and analysis was based on proportionate mortality ratios comparing deaths from specific causes to all causes in firefighters. The study identified there was increased levels of malignant neoplasms (PMR=110; 106-114), rectal cancer (PMR=148; 105-205), skin cancer (PMR=163; 115-223), kidney cancer (PMR=144 108-189), lymphatic and haematopoietic cancers (PMR=130 111-151) and multiple myeloma (PMR=148 102-207).	++	The study identified an elevated risk of kidney cancer (PMR=144, 108-189).
Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Kidney cancer had a reduced risk which was statistically significant with an SMR=0.27 (0.03-0.97) based on 2 deaths. This cancer did not feature in any of the analyses for surrogates of exposure.
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Kidney cancer had an SIR=0.5 (0.1-1.6) based on 3 registered cases. No data based on exposure were presented for this cancer.

Golden *et al* 1995 A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain,; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.

+

The authors do not illustrate their findings for kidney cancer, describing the various studies (eight) as not showing consistently elevated risks. No summary risk estimate is presented.

Guidotti 1993 Cause of death was examined for two cohorts totalling 3,328 firefighters from Edmonton & Calgary (Alberta) in Canada. The firefighters were active from 1927-1987. Data was analysed over the entire cohort; by entry date; for latency as years since entry; and for duration of employment. Mortality from all causes was close to expected (SMR=96, 87-107) as was that for heart disease (SMR=110, 92-131). Statistically significant excesses were observed for: all malignant neoplasms (SMR=127, 102-155); kidney & ureter cancers (SMR=414, 166-853); and mental disorders (SMR=455, 274-711). Only isolated excesses were apparent from any of the latency or exposure-related analyses.

++

Kidney cancer (ICD 9 189) had a significantly elevated risk SMR=414, (166-853), based on 7 deaths. Analysis by entry date did not show any significantly elevated risks or any particular trend although the oldest sub-cohort had the highest (non-significant) risk estimate (<1920: 1728; 1950s: 334; 1960s: 516). No SMRs were reported for the other sub-cohorts. The analysis for latency and estimated exposure index had no entries for most cells. For "all subjects", the 40-49 years sub-cohort had a significantly elevated risk (1393) with (non-significant) entries against two other sub-cohorts (<20 years: 408; 20-29 years: 392). In the index categories, one death in the 0 index: 20-29 years category gave a risk estimate of 3997. A further single death in the >0-<1 index 20-29 years category gave an estimate of 2056. Finally, 1 death in the >=10 index, <20 years gave an estimate of 758; a further death in the 20-29 years sub-cohort gave an estimate of 254; whilst 4 deaths in the 40-49 years sub-cohort for the same index value gave a significant estimate of 2654. Kidney cancer also featured in an analysis of mortality by duration of employment where a significant risk was identified amongst those who were employed the longest (40+ years 3,612) but no particular trend was apparent in the preceding years.

Guidotti, 1995	Reviews studies of mortality in firefighters. Appears to have included all the main studies identified elsewhere but fails to describe process of identifying and selecting papers. Text summarises major findings and table presents SMR (or PMR) values and confidence intervals. Overall summary table presented as the approximate magnitude of any associations as 100, 150 or 200, presumably signifying relative risk (base 100). These are presumably based upon an interpretation of the accumulated evidence but the method of their derivation is not given. Basis of selection for chosen outcomes to address is not given, described as "specific outcomes of interest". Not all outcomes referred to in text are covered in final table. Thus, the text refers to genitourinary cancers (excluding bladder cancer) as "relatively uncommon cancers...and the risk appears to be high, close to or in excess of a doubled relative risk." Only bladder cancer data abstracted in study summaries and overall summary of associations.		Cites risk estimates from 11 papers, four of which do not have confidence intervals. These estimates range from 27-414 and 3/11 are less than 100. On this basis the author concludes that there is a likely association between firefighting and kidney cancer with an approximate magnitude of 150.
Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Cancer of the stomach yielded an SMOR=0.97 (0.69-1.35) based on 46 registrations. No trend was apparent in the age-stratified data: 18-54: SMOR=2.02 (0.57-7.15); 55-74: SMOR=0.73 (0.41-1.27); 75+: SMOR=0.94 (0.38-2.36).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The meta-analysis across all forms of study, utilising a total of 13 analyses, yielded a significant Summary Risk Estimate of 1.22 (1.04 –1.44) for cancer of the stomach. This was lower than the meta-SMR of 1.58, (1.12-2.16) and the heterogeneity of the data was not significant at the 10% level.

Ma <i>et al.</i> , 1998	<p>A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.</p>	+	<p>Amongst white firefighters, cancer of the stomach had an MOR=1.2 (0.9-1.6), based on 52 deaths. For black firefighters the MOR was 1.2 but there were insufficient deaths (3) for a confidence interval to be computed.</p>
Ma <i>et al.</i> , 2006	<p>A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.</p>	++	<p>Fourteen registered cases of stomach cancer amongst the male cohort yielded a SIR=0.50 (0.25-0.90). No cases of this cancer were recorded amongst the female cohort.</p>

Tornling <i>et al.</i> 1994	An investigation of cancer incidence and mortality rates in Swedish firefighters. All male firefighters employed for at least one year in the City of Stockholm between 1931 and 1981 were traced. This resulted in 1,153 individuals but a further group were already deceased so the total sample size was 1,116 males. Exposure measures were also made using a 10% sample of fire reports which was developed into an exposure index for each calendar year and each fire station. Standardised mortality ratios were calculated. The analysis identified that overall mortality was lower than expected (SMR=82; 72-91). The cancer incidence was equal to expected but increased stomach cancer was observed (SMR=192; 114-304) and brain cancer (SMR 496; 135-270).	++	Twelve deaths from stomach cancer resulted in an SMR=121 (62-211). However, the incidence of stomach cancer was significantly elevated (SIR=192, 114-304). Analyses of stomach cancer incidence were also conducted by age; years of employment; latency (years since first employment); and number of fires attended. There were elevated risks amongst those employed for >30years (SIR=289, 149-505); for latencies of <30 years (SIR=481, 155-1122) and 30-40 years (SIR=606, 313-1059) (but not >40 years); and for those who attended >1,000 fires per year (SIR=264, 136-461). None of the equivalent mortality analyses yielded significant results although the SMRs did suggest similar trends.
Vena and Fiedler, 1987	A mortality study of all full-time municipal employees of Buffalo USA for a minimum of 5 years between 1950 and 1979. Individuals who had worked at least one year as a firefighter were included. At data collection this was 1,867 white male firefighters including 890 currently employed, 740 retirees, 65 who had resigned and 172 who died in service. The analysis identified that firefighters had significantly more benign neoplasms (SMR=4.17; 1.34-9.73), malignant neoplasms including colon cancer (SMR=1.83; 1.05-2.97), and bladder cancer (SMR=2.86; 1.30-5.40).	++	Seven deaths from stomach cancer amongst the cohort yielded an SMR=1.19 (0.48-2.46). Cancer of the oesophagus did not feature in subsidiary analyses of firefighters with estimates of exposure. Although not analysed separately there were indications of a possible trend with years worked as a firefighter for all cancers of the digestive system (ICD 9, 150-159): 1-9 years: 0.67; 10-19 years: 0.40; 20-29 years: 0.78; 30-39 years: 1.33; 40+ years: 3.08. The final Risk Ratio was statistically significant.
Youakim, 2006	An analysis of 16 studies of the risk of cancer among firefighters. The study identified an increase in risk of kidney cancer (sumRR 1.25; 1.02-1.43) and non-Hodgkin's Lymphoma (sumRR 1.4; 1.20-1.60). Further analysis using a sub-cohort of studies was also made based on duration of employment with 30 years or more as a firefighter had an increased risk for colon cancer (sumRR 1.51; 1.05-2.11), kidney cancer (sumRR 36.12; 1.70-16.00), brain cancer (sumRR 2.53; 1.27-7.07) and leukaemia (sumRR 2.87 1.43-5.14). After 40 years employment risks for mortality from colon cancer were (sumRR 4.71; 2.03-9.27), kidney cancer (sumRR 36.2; 4.03-120.42) and bladder cancer (sumRR 5.7; 1.56-14.33).	++	

3.2.18 Ocular Cancer

Two papers were found which presented risk estimates for ocular cancer. These were the incidence studies of Demers *et al* (1994) and Ma *et al* (2006). These yielded estimates of 5.2 (0.6-18.8) and 1.54 (0.42-3.95) based on two and four cases respectively, derived from a total of almost 450,000 person-years. Clearly, with such a limited evidence-base no clear conclusions can be derived for this form of cancer.

3.2.19 Brain Cancer

Seventeen papers relating to studies of the mortality (14) or morbidity (3) of brain cancer in firefighters were identified for the review. In addition, six reviews which presented coverage of this topic were also selected. Figure 15 illustrates the relative risks identified in the main findings of each of the studies reporting a risk estimate and confidence interval and Table 15 presents the evidence in table format.

Allowing for some possible partial duplications of results between studies (which would effectively merge some of the negative (protective) and neutral outcomes, it is clear that a predominance of studies have demonstrated a positive association between brain cancer and firefighting, four of which were statistically significant. All were mortality studies and there does not appear to have been any overlap in the cohorts used, which were drawn from Hawaii; Toronto; California; Seattle; Portland and Tacoma; and Massachusetts.

The cohort sizes of these four ranged from 205 deaths in the study by Grimes *et al* (1991) to the study of 4,306 firefighters encompassing 1,169 deaths reported by Demers *et al.*, 1992a. With the exception of the particularly large cohort studied by Ma and co-workers (2005, 2006) which studied in excess of 34,000 male firefighters in Florida, or the multi-state studies of Ma and colleagues Ma *et al.*, 1998 and Burnett *et al.*, 1994 these sizes are comparable to those not yielding significant findings. The numbers of brain cancer deaths (or incidences) in each study are also reasonably comparable, with most within the range of 3-14 deaths. One notable exception is the study by Kang *et al* (2008) where 28 brain cancer deaths were identified.

Some other studies also reported significant associations, but only in the analysis of subgroups (Aronson *et al.*, 1994, Tornling *et al.*, 1994, Vena *et al.*, 1987).

Vena and Fiedler (1987) report on an analysis of mortality due to brain cancer by years worked as a firefighter. The risk ratio was elevated for the first two decades (1-9; 10-19) at 3.33. No confidence interval is reported but it is presented as not statistically significant. However, in the third decade (20-29) this rises to 3.75 and attains significance ($p=0.05$). Latency (years since first employment) also reveals significant effects with significantly elevated risk ratios for both <20 years (4.02) and 20-29 years (4.58).

Demers *et al.*, (1992a) also reported analyses by years of service and latency. In this instance, an increased risk in going from fewer than 10 years of employment (SMR=2.57, 0.8-6.0) to 10-19 years (SMR=3.53, 1.5-7.0) is not sustained in subsequent years (20-29, SMR=1.24; ≥ 30 , SMR=2.04) and only a latency in excess of 30 years presents a significant association (2.63, 1.4-4.4).

Tornling *et al* (1994) provides a further level of analysis. Stockholm fire brigade records documented all fires fought since around 1900. From these, an exposure index of the approximate number of fires fought by a firefighter at any one station was derived, along with a measure of SCBA use. These could then be assigned to

each firefighter as an index of likely exposure to potentially harmful materials. Increasing trends in computed SMRs were obtained for analyses of years of employment; latency; and number of fires fought annually for both incidence and mortality from brain cancer. None of those for cancer incidence attained statistical significance. However, the highest number of fires fought (>1,000 per year) was associated with the highest level of mortality (SMR = 496) which attained statistical significance (CI, 135-1270). Latency demonstrated an inverted V relationship with only the central sub-cohort attaining significance (507, 105-1481).

Finally, Aronson *et al.*, (1994), who had found a significant main association (SMR=201, 110-337) carried out analyses based on years since first exposure, years of employment and age. No pattern was apparent for years since first exposure with only the most recent cohort (<20 years) attaining statistical significance with an SMR of 283 (104-616). SMRs for subsequent cohorts were smaller and did not attain statistical significance. Years of employment, used by a number of studies as the main surrogate for exposure, failed to demonstrate any significant relationships and again there was no particular trend apparent across the three sub-cohorts used. Finally, subdividing the cohort by age (<60 years; ≥60 years) yielded two very similar SMRs of 199 and 204 respectively which again were not statistically significant.

Kang *et al* (2008) reported the use of the police cohort as a comparator, yielding an SMOR of 1.90 (1.00-3.26) which implied a significantly elevated risk over this sub-cohort.

Of the 17 papers, eight presented an estimate of person-years of follow-up (or equivalent). These totalled 1,303,607 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al.* 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

As stated earlier, six review papers were identified which considered any association between brain cancer and the occupation of firefighting. The oldest of these, dating from 1990, is that by Howe and Burch (1990). The authors utilised seven papers (four cohorts; three proportionate mortality studies) of which all but two (Howe and Lindsay, 1983; Petersen and Milham, 1980), which were both general population studies, identified an elevated risk. However, the first of these papers did not identify any cases of brain cancer amongst its sub-cohort of firefighters and, with a very low expected level (0.6) might well have lacked the necessary sensitivity.

Analysing the two sets of papers separately (cohort and PMR) yields very similar risk estimates (1.43 and 1.45) neither of which attains statistical significance. However, combining the studies yields a combined relative risk of 1.44 (1.07-1.89), indicating a significant association. The authors note that, for the two studies where data was provided (Heyer *et al*, 1990; Ven and Fiedler, 1987), there was no apparent dose-response relationship.

There were two reviews published in 1995, those by Guidotti and Golden *et al.* As referred to for cancer of the colon, the derivation of the studies for inclusion by Guidotti is not stated, nor is the method used to derive the overall association cited. Sixteen risk estimates are cited, ranging from 0-279. The value of zero is cited as stemming from Howe and Burch (1990) although, from the details cited, appears actually to have been extracted from Howe and Lindsay (possibly a secondary citation). Excluding this yields a lower limit of 81. Seven of the 16 estimates are less than 100. Commenting on the wide variation in values the author refers to the small numbers of cases on which the risk estimates are based but concludes that cancer of the brain and central nervous system might be occupationally associated with work

as a firefighter, assigning an approximate risk magnitude of 200 (which the author relates to the legal criterion of 'more likely than not').

Guidotti (1995) includes a tabulation of the recommendations from the review, compared to those made by the Industrial Disease Standards Panel (of Ontario) (1994) Guidotti, 1995. It is not clear whether the paper was prepared as a submission to this panel. According to the summary tabulation, the Panel accepted an apparent association although the author lists as rebuttal criteria; heritable neoplasm's (rare); previous vinyl chloride exposure; and radiation to the head.

Golden *et al.*, (1995) cite 12 studies, displaying a marked predominance of positive associations. The authors indicate that excess risk appears to be most notable within 15-30 years of exposure. No composite risk ratio is determined although the authors do cite that calculated by Howe and Burch (1990) although they utilise the value derived from the cohort studies (1.43, 93-212) rather than the combined value.

Haas *et al* (2003) restricted their review to cohort mortality studies of firefighters which reported an SMR or an equivalent statistic (Haas *et al.*, 2003). They excluded the smaller of any overlapping studies. The focus of the paper was specifically that of latency and the authors identified four papers (all included in the present review) with data on brain cancer. Exposure was modelled in the three ways: years of service; time since first employment (latency); and, in one paper (Tornling *et al*, 1994) number of fires. Years of service provided slightly contradictory findings. Vena and Fiedler (1987) identified the highest SMR with the oldest sub-cohort (20-29 years) (3.75, $p=0.05$) whilst Demers *et al* (1992a) identified an intermediate sub-cohort (10-19 years) (3.53, $p=0.05$). Tornling *et al* (1994) showed a clear trend of increasing association with increasing years of service but even the SMR for the oldest group (>30 years) SMR=3.25 was not statistically significant. Aronson *et al* (1994) showed elevated SMRs for all cohorts but none attained statistical significance. A similarly confused pattern emerged for latency with Vena and Fiedler (1987) and Aronson *et al* (1994) finding the largest associations with shorter latencies (Vena and Fiedler, <20 years, SMR=4.02, $p=0.05$; 20-29 years, SMR=4.58, $p=0.05$; Aronson *et al*, <15 years, SMR=2.83, $p=0.05$) whilst, for Demers *et al* (1992a) the longest latency period demonstrated the highest association (2.63, $p=0.05$). Tornling *et al* (1994) again showed an apparent increasing trend but no sub-cohort values attained significance.

This same paper also analysed data by estimated number of fires. Although the two higher categories had elevated SMRs (2.82; 2.01) neither attained statistical significance. It should be noted that none of the three sub-categories analysed these authors had any cancers in the first sub-cohort.

The two most recent reviews were those of Youakim, (2006) and LeMasters *et al.*, (2006). Youakim (2006) identified 14 papers (again excluding overlapping cohorts), focussing on mortality, either from specific cohorts or from population mortality studies. Collectively, these papers yielded a summed Risk Ratio of 1.09 (0.92-1.25) with a marginally higher ratio for cohort studies alone (1.14, 0.90-1.41). For incidence/morbidity studies, six papers yielded a summed Risk Ratio of 1.39 (0.90-2.05), slightly lower for the three cohort studies (1.25, 0.68-2.10). However, the author does find that, combining studies utilising years of employment as a surrogate for exposure, yields a combined Risk Ratio of 2.53 (1.17-7.07) for 30 or more years of employment.

This paper utilises the results from two mortality studies not encompassed by the present review, which extend back over a considerable period of time (starting in

1915, and 1945). These cover a period where firefighting would have been very different, in terms of the exposure risks faced; the manner of working; and the protection provided. The author also uses the larger sample period cited by Bates *et al* (2001) rather than the smaller but more reliable cohort preferred by the authors. It also does not include the recent study by Bates (2007) which showed a significant positive association from a major cancer registry study (1.35, 1.06-1.72). Nevertheless, this review does suggest that a degree of caution is required in drawing any conclusions over any association between brain cancer and firefighting.

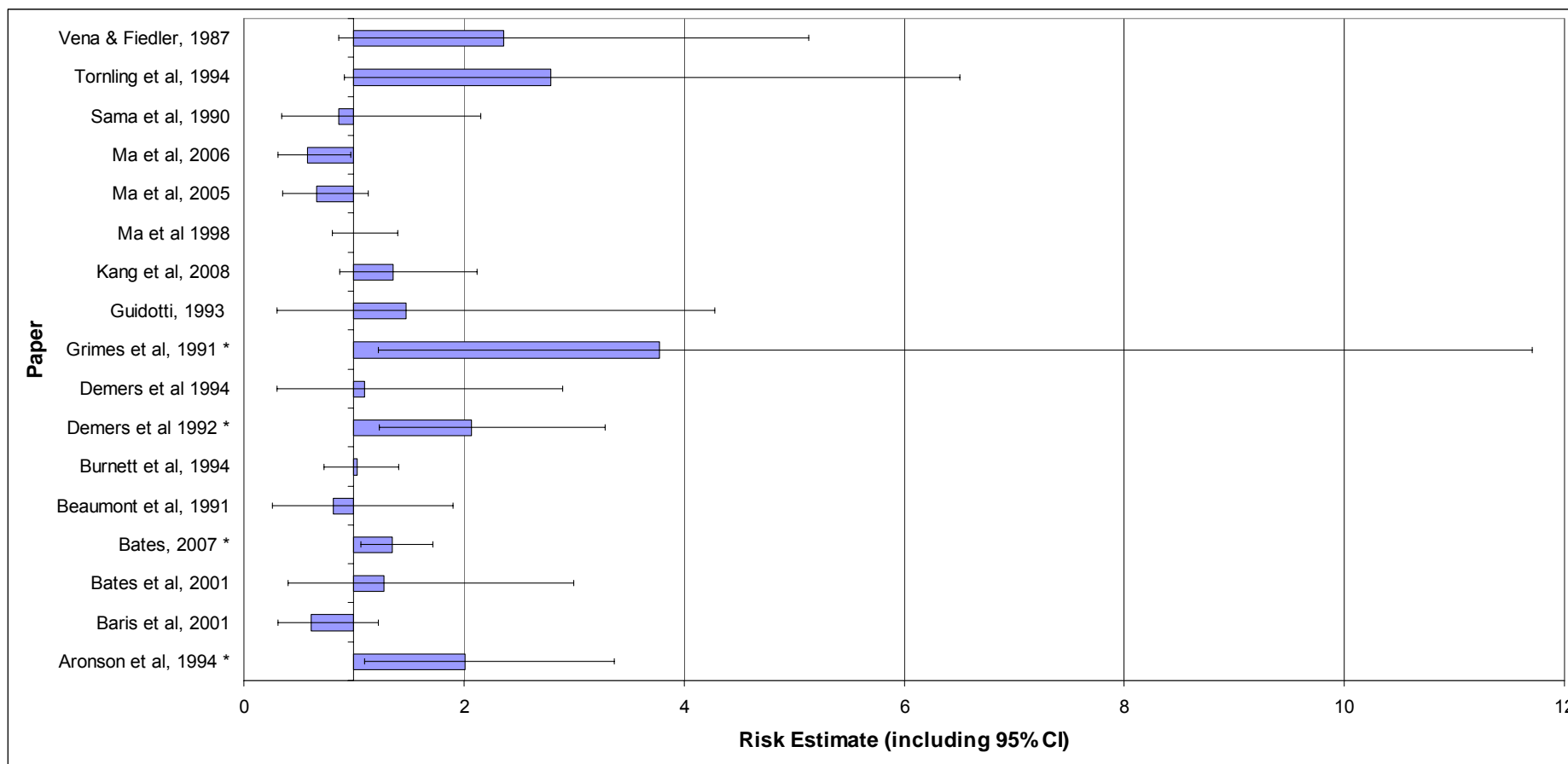
The material used by LeMasters *et al* (2006) in a meta-analysis of brain cancer, included three general occupational mortality studies; four PMR mortality studies; two studies of relative risk; three SIR (incidence) studies and two case-control/mortality Odds Ratio studies. Again, the authors erroneously include the study of firefighters and police (Demers, *et al.*, 1992b) rather than the equivalent cohort of firefighters alone Demers *et al.*, 1994

As before, the authors calculated separate summed estimates of risk for each type of study as well as an overall summed estimate derived from pooling all of the study results. The various summed estimates obtained were SMR=1.39 (0.94-2.06); PMR=1.17 (0.90-1.49); RR=1.26 (0.55-2.34); SIR=1.23 (0.75-1.93) and the two separate OR studies with values of 1.0 (0.80-1.40) and 1.52 (0.32-2.92) for mortality and incidence respectively. Summing the results from these 19 studies, an overall pooled summary Risk Estimate of 1.32 (1.12-1.54) was calculated. Although there clearly was some variance between studies the heterogeneity calculation in this instance was not statistically significant ($p>0.10$).

In this instance, the three more recent papers omitted from the analysis, but included in the present review, provide conflicting results. The incidence and mortality studies of Ma *et al* (2005, 2006) show a marked (but non-significant) negative association, whilst the incidence study of Kang *et al* (2008) produced a smaller, positive association which was again non-significant. The mortality study of Ma *et al* (2005) yielded an SMR of 0.66 (0.35-1.13), falling outside the confidence interval of the estimate by Le Masters and co-workers. Similarly, the statistically significant SIR value derived by Ma *et al* (2006) of 0.58 (0.31-0.97) was outside the CI range for these studies. The morbidity statistic (SMOR) from Kang *et al* (2008), at 1.36 (0.87-2.12), fell within the ranges of the morbidity estimates considered by Le Masters and colleagues.

Drawing these results together, it appears that there are some indications of an association between brain cancer and firefighting although the overall elevation of risk is relatively modest and less than 2.0. Analyses of any sub-cohort in an attempt to explore the possibility of a dose-response relationship is unclear with some exposure surrogates suggesting a shorter latency and others implying a conventional dose-response relationship with longer periods of employment equating to increased risk.

Estimates of the likely scale of any effect with any precision is difficult, especially given recent, conflicting results but it would seem likely that, adding the data from the three recent studies to those reviewed earlier, a risk estimate for brain cancer amongst firefighters of the order of 1.2 (1.0-1.4) would seem likely.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 15: Comparisons of relative risks (with 95% confidence intervals) for brain cancer, derived from published studies

Table 15. Evidence relating Fire Fighting and Brain Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	<p>Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.</p>	++	<p>There were 14 deaths attributed to brain cancer (ICD 9, 191-192) in the cohort, yielding a significant SMR of 201 (110-337). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of these deaths.</p> <p>Further analysis by years since first exposure showed a significant excess risk amongst those employed for the shortest time, which was not sustained in later sub-cohorts: <20 years: SMR=283 (104-616); 20-29 years: SMR=99 (12-656); >=30 years: SMR=212 (78-462). An analysis by years of employment did not show this trend: <15 years: SMR=262 (85-611); 15-29 years: SMR=106 (22-310); >=30 years: SMR=229 (75-535). Finally, an analysis of deaths by age showed no difference in risk between the two sub-cohorts: <60 years: SMR=199 (95-366); >=60 years SMR=204 (56-522).</p>

Baris *et al.*, 2001 Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations. ++

Eight deaths attributed to brain cancer (ICD 9, 191-192) yielding a non-significant SMR of 0.61 (0.31-1.22). In the analysis of duration of employment as a surrogate for exposure there was no linear trend across the three categories, which all showed risk estimates less than 1.0: (≤ 9 years, SMR=0.47 (0.12-1.89); 10-19 years, SMR=0.44, (0.11-1.75); ≥ 20 years, SMR=0.94; 0.35-2.49). Using the alternative measure of exposure, there was no particular pattern with deaths in only two of the three sub-cohorts: (engine company: SMR=1.02, (0.43-2.46); ladder company: no deaths; both ladder and engine companies: SMR=0.43, (0.14-1.35)). There were suggestions that those recruited longest ago were likely to show less mortality than those recruited more recently. (pre-1935: SMR=0.36 (0.05-2.57); 1935-1944: SMR=0.70, (0.23-2.17); post 1944: SMR=0.66, (0.25-1.77)).

Bates <i>et al</i> , 2001	<p>This was an historical cohort study of mortality and cancer incidence in all paid New Zealand fire fighters, from 1977 to 1995 consisting of 4,221 male firefighters. The only cancer for which this study provided evidence of an increased risk was testicular cancer. In the whole cohort, over the whole study period, the risk was non-significant with an SIR=1.55 (0.8-2.8). However, when the analysis was restricted to that period for which better quality cancer registration data were considered to be available (1990-1996) this yielded a significant association with an SIR=3.0 (1.3-5.90).</p>	+	<p>In the whole-period analysis (1977-1996) brain cancer had a non-significant SIR=1.27 (0.4-3.0) based upon seven cancers. Over the shorter period for which there was considered to be more complete data (1990-1996), there were three such cancers yielding a slightly higher SIR=1.59 (0.3-4.6).</p> <p>Analysis of the data by years of service did not feature this cancer. Mortality over the whole period had a reduced but non-significant SMR=0.68 (0.1-2.4).</p>
Bates 2007	<p>Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).</p>	+	<p>The occupation of fire-fighting was significantly associated with an increased risk of brain cancer (Odds Ratio=1.35, 1.06-1.72), based on 71 registered cases. Reporting trends were analysed by subdividing the results into two sub-cohorts, covering registrations in 1988-1995 and 1996-2003. This showed both sub-cohorts with an elevated risk, although only that for the older registrants was significant: older registrants OR=1.63 (1.05-2.52); younger registrants: OR=1.08 (0.68-1.72).</p>

Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for brain cancer was less than 1.0, but not significantly (0.81, 0.26-1.90), based on 5 deaths. Exposure-related data was not reported for this cancer.
Burnett <i>et al.</i> , 1994	Assessment of mortality rates for firefighters using information from 27 USA states between 1984-1990. In total 5,744 deaths in white male firefighters were reviewed and analysis was based on proportionate mortality ratios comparing deaths from specific causes as compared to all causes in firefighters. The study identified there was increased levels of malignant neoplasms (PMR=110; 95% CI 106-114), rectal cancer (PMR=148; 95% CI 105-205), skin cancer (PMR=163; 95% CI 115-223), kidney cancer (PMR=144; 95% CI 108-189), lymphatic and haematopoietic cancers (PMR=130 95% CI 111-151) and multiple myeloma (PMR=148; 95% CI 102-207).	++	The PMR for brain cancer was barely distinguishable from 1.0: PMR=103, (73-141) based on 37 deaths.

Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Brain cancer (ICD 9 191-192) had a significantly elevated SMR=2.07 (1.23-3.28) based on 18 deaths. An analysis by duration of exposed employment showed no particular trend, with an elevated risk throughout although only that for the 10-19 years sub-cohort was statistically significant: <10years: SMR=2.57 (0.8-6.0); 10-19 years: SMR=3.53 (1.5-7.0); 20-29 years: SMR=1.24 (0.5-2.7); > 30 years: SMR=2.04 (0.4-5.9). A similar analysis by years since first employment showed a significant excess only in the oldest sub-cohort: <20 years: SIR=2.45, (0.9-5.3); 20-29 years: SIR=0.73, (0.1-2.6); 30+ years: SIR=2.63 (1.4-4.4). Finally, the authors analysed the data by age at risk, which showed the youngest sub-cohort to be at a significantly increased risk from brain cancer: 18-39 years old: SMR=3.75 (1.2-8.7); 40-64 years old: SMR=1.66 (0.8-3.0); >65 years old: SMR=2.34 (0.9-5.1).
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Brain cancer had an SIR=1.1 (0.60-2.9) based on 4 deaths. An analysis by duration of exposed employment showed no particular pattern: <10 years: 1.6 (0.0-8.8); 10-19 years: 0.0 (0.0-4.6); 20-29 years: 1.6 (0.3-4.6); 30+ years: 0.0 (0.0-16). A similar analysis by years since first employment also showed no particular pattern: <20 years: SIR=0.0 (0.0-7.1); 20-29 years: 0.0 (0.0-4.5); SIR=30+ years: SIR=1.9 (0.5-4.9).

Grimes <i>et al</i> 1991	<p>A twenty year Proportionate Mortality study was conducted with all male firefighters in the City of Honolulu from 1969-1988 who had at least one year of service. This covered 205 deaths. Significant increases in risk of death were found for brain cancer (ICD 9, 191-192) (PMR=3.78, 1.22-11.71); prostate cancer (ICD 9 185) (PMR=2.61, 1.38-4.97); and cirrhosis of the liver (ICD 9 571) (PMR=2.3, 1.21-4.37). It was suggested that the latter could, at least in part, be attributed to an excess of alcohol consumption in this group. A significant decrease in mortality was observed for respiratory diseases (ICD 9 460-519) (PMR=0.37, 0.17-0.81).</p>	+	<p>The PMR for brain cancer (ICD 9, 191-192) was significantly elevated at 3.78 (1.22-11.71) based upon 3 deaths. A subsidiary analysis for firefighters of Caucasian or Hawaiian extraction yielded values of 4.15 (1.04-16.51) and 3.60 (0.49-26.46) based upon three and two deaths respectively.</p>
Golden <i>et al</i> 1995	<p>A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and some of the research on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness. Cancers summarised are: brain; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.</p>	+	<p>Cites 12 studies displaying a marked predominance of positive associations. The authors indicate that excess risk appears to be most notable within 15-30 years of exposure. No summary risk estimate is presented.</p>

Guidotti 1993	Cause of death was examined for two cohorts totalling 3,328 firefighters from Edmonton & Calgary (Alberta) in Canada. The firefighters were active from 1927-1987. Data was analysed over the entire cohort; by entry date; for latency as years since entry; and for duration of employment. Mortality from all causes was close to expected (SMR=96, 87-107) as was that for heart disease (SMR=110, 92-131). Statistically significant excesses were observed for: all malignant neoplasms (SMR=127, 102-155); kidney & ureter cancers (SMR=414, 166-853); and mental disorders (SMR=455, 274-711). Only isolated excesses were apparent from any of the latency or exposure-related analyses.	++	Brain cancer (ICD 9 191-192) had an SMR=147, (30-429) but did not feature in any breakdown analyses by entry date or other exposure surrogates.
Guidotti, 1995	Reviews studies of mortality in firefighters. Appears to have included all the main studies identified elsewhere but fails to describe process of identifying and selecting papers. Text summarises major findings and table presents SMR (or PMR) values and confidence intervals. Overall summary table presented as the approximate magnitude of any associations as 100, 150 or 200, presumably signifying relative risk (base 100). These are presumably based upon an interpretation of the accumulated evidence but the method of their derivation is not given. Basis of selection for chosen outcomes to address is not given, described as "specific outcomes of interest". Not all outcomes referred to in text are covered in final table. Thus, the text refers to genitourinary cancers (excluding bladder cancer) as "relatively uncommon cancers...and the risk appears to be high, close to or in excess of a doubled relative risk." Only bladder cancer data abstracted in study summaries and overall summary of associations.	-	Cites risk estimates from 16 papers, four of which do not have confidence intervals. These estimates range from 0-279 and 7/16 are less than 100. On this basis the author concludes that there is a likely association between firefighting and brain cancer with an approximate magnitude of 200.

Haas *et al*, 2003 Haas *et al* (2003) restricted their review to cohort mortality studies of firefighters which reported an SMR or an equivalent statistic. They excluded the smaller of any overlapping studies. ++

Howe and Burch, 1990 Review paper from 1990. Looked at 'all cancers' and "those specific cancers which individual studies have reported to show an association with the occupation of fire fighter". Lung, colon, brain, malignant myeloma and multiple myeloma were chosen. Studies with any demonstrable major bias were excluded (not listed). Note that much work on testicular cancer (e.g. early Bates *et al* study from 1995) would not be covered. Pooled estimate showed sig all cause reduced risk (0.92, 0.85-0.98) in SMR but increased (1.09, 1.01-1.17) PMR which authors dismiss as artefact of healthy worker effect. For lung cancer the pooled SMR/PMR values were 0.92/1.08, neither of which were sig. Pooling colon cancer studies again yielded non-sig effects (SMR, 1.12, PMR, 1.06). For brain tumours the pooled SMR of 1.43 and PMR of 1.45 narrowly missed sig (CI, 0.93-2.12 & 0.95-2.12 respectively). Authors point out that the main study unsupportive of an effect related primarily to pre-WW2 exposures when, it is hypothesised, exposures to carcinogens would have been less. No dose-response relationship has been seen but causation is seen as biologically plausible. Sig increased risk of malignant melanoma based on pooled estimate of 1.73 from 5 studies. Exposure-response relationship also seen. However, authors regard causal connection as implausible with high risk of confounding. For multiple myeloma, increased pooled risk of 1.51 is not sig. This value is distorted by high value (10.00) in 1 study. +

The authors identified four papers (all included in the present review) with data on brain cancer. Exposure was modelled in the three ways: years of service; time since first employment (latency); and number of fires (based on one paper). Only one paper showed any consistent trend.

The authors identified seven papers (four cohorts; three proportionate mortality studies) of which all but two (Howe and Lindsay, 1983; Petersen and Milham, 1980), both general population studies, identified an elevated risk. However, the first of these papers did not identify any cases of brain cancer amongst its sub-cohort of firefighters and, with a very low expected level (0.6) might well have lacked the necessary sensitivity. On the basis of these papers they calculated a summed SMR=1.43 (0.93-2.120; and a summed PMR=1.45 (0.95-2.12).

Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This included 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations. There was an increased risk for colon cancer (SMOR 1.36; 1.04-1.79) and brain cancer (SMOR 1.9; 1.10-3.26). One drawback was the fact that occupational data was obtained from medical records.	++	Brain cancer yielded an SMOR=1.36 (0.87-2.12) based on 28 registrations. No trend was apparent in the age-stratified data: 18-54: SMOR=2.03 (0.79-5.25); 55-74: SMOR=1.70 (0.80-3.60); 75+: SMOR=2.78 (0.64-12.04).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The authors concluded that there was a possible association between firefighting and brain cancer. The meta-analysis across all forms of study, utilising a total of 19 analyses, yielded a significant Summary Risk Estimate of 1.32 (1.12 –1.54). This was slightly higher than the meta-SMR and PMR of 1.27, (0.98-1.63) and the heterogeneity of the data was not significant at the 10% level although there was heterogeneity among the SMR studies.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white and 66 black firefighters. Mortality odds ratios were calculated for both groups using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 1.1-1.2), lip (MOR=4.9; 1.9-18.3), pancreas (MOR=1.2; 1.0-1.5), bronchus and lung (MOR=1.1; 1.0-1.2), soft tissue sarcoma (MOR =1.6; 1.0-2.7), melanoma (MOR=1.4; 1.0-1.9), prostate (MOR=1.2; 1.0-1.3), kidney and renal pelvis (MOR=1.3; 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 3.0-16.0), colon cancer (MOR=2.1; 1.1-4.0), prostate cancer (MOR=1.9; 1.2-3.2) and nasopharynx (MOR=7.6; 1.3-46.4). The Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, brain cancer had an MOR=1.0 (0.8-1.4), based on 41 deaths. For black firefighters the MOR was significantly elevated: MOR=6.9 (3.0-16.0), based on five deaths.

Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	13 deaths from brain cancer amongst the male cohort yielded an SMR=0.66 (0.35-1.13). No deaths from this cancer were recorded amongst the female cohort. A subsidiary analysis of eight deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave a very similar outcome with SMR=0.62 (0.27-1.23).
Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	Fourteen registered cases of stomach cancer amongst the male cohort yielded a SIR=0.58 (0.31-0.97) which was significantly less than 1.0. No cases of this cancer were recorded amongst the female cohort.

Sama <i>et al.</i> , 1990	A study using cancer registry data from Massachusetts in the USA. Samples included 315 male cancer cases between 1982 and 1986; 392 male white police officers and 29,277 State cases. The analysis included SMORS and it was identified that there was an elevated risk of melanoma (SMOR=292; 95% CI 170-503), bladder cancer (SMOR 159; 95% CI 107-414) for firefighters compared to State residents. In comparison with police officers, there was an increase risk in bladder cancer (SMOR=211; 95% CI 107-414) and non-Hodgkin's Lymphoma (SMOR=32; 95% CI 119-898). A number of difficulties with the study were identified by the researchers including the potential for underreporting of cancers.	++	Five deaths from brain cancer yielded an SMOR=86 (34-215). Brain cancer did not feature in the subsequent age-related analysis.
Tornling <i>et al.</i> 1994	An investigation of cancer incidence and mortality rates in Swedish firefighters. All male firefighters employed for at least one year in the City of Stockholm between 1931 and 1981 were traced. This resulted in 1,153 individuals but a further group were already deceased so the total sample size was 1,116 males. Exposure measures were also made using a 10% sample of fire reports which was developed into an exposure index for each calendar year and each fire station. Standardised mortality ratios were calculated. The analysis identified that overall mortality was lower than expected (SMR=82; 95% CI 72-91). The cancer incidence was equal to expected but increased stomach cancer was observed (SMR=192; CI 114-304) and brain cancer (SMR 496; 95% CI 135-270).	++	Five deaths from brain cancer resulted in an SMR=279 (91-651). The same number of recorded cases gave a lower morbidity ratio: SMR=137 44-320. Analyses of brain cancer incidence were also conducted by age; years of employment; latency (years since first employment); and number of fires attended. All of the cases occurred amongst the oldest sub-cohort: 65+: SMR=435, (140-1015). Most of the cases (4/5) occurred amongst those those employed for >30years (SIR=325, 87-833); for latencies of 30-40 years (SIR=185, 21-669) and >40 years (SIR=270, 54-790); and for those who attended 800-1000 (SIR=282, 32-1017) and >1,000 fires per year (SIR=201, 40-588). Two sub-cohorts in the equivalent mortality analyses yielded significant results and the general trends were similar. (30-40 years latency: 507, 105-1481); >1,000 fires: 496, 135-1270).

Vena and Fiedler, 1987	A mortality study of municipal workers which all full-time employees of Buffalo USA between 1950 and 1979 for a minimum of 5 years. Individuals who had worked at least one year as a firefighter were included. At data collection this was 1,867 white male firefighters including 890 currently employed, 740 retirees, 65 who had resigned and 172 who died in service. The analysis identified that firefighters had significantly more benign neoplasms (SMR=4.17; 95% CI 1.34-9.73), malignant neoplasms including colon cancer (SMR=1.83; 95% CI 1.05-2.97), and bladder cancer (SMR=2.86; 95% CI 1.30-5.40).	++	Six deaths from brain cancer amongst the cohort yielded an SMR=2.36 (0.86-5.13). There were no indications of a possible trend with years worked as a firefighter: 1-9 years: 3.33; 10-19 years: 3.33; 20-29 years: 3.75; 30-39 years: no deaths; 40+ years: no deaths. The increase in Risk Ratio for the 20-29 years sub-cohort was statistically significant. There was significantly increased mortality in two sub-cohorts analysed by calendar year of death: 1950-1959: O/E=5.0; 1960-1969: no deaths; 1970-1979, O/E=2.73. Analysis by year of hire also identified an excess of observed over expected deaths in one sub-cohort (1940-1949: O/E=4.94). Finally a latency analysis showed deaths in only the first two cohorts, both of which had significant excesses: <20 years: O/E=4.02; 20-29 years O/E=4.58.
Youakim, 2006	An analysis of 16 studies to identify risk of cancer among firefighters. The study identified an increase in risk of kidney cancer (sumRR 1.25; 95% CI 1.02-1.43) and non-Hodgkin's Lymphoma (sumRR 1.4; 95% CI 1.20-1.60). Further analysis using a sub-cohort of studies was also made based on duration of employment with 30 years or more as a firefighter had an increased risk for colon cancer (sumRR 1.51; 95% CI 1.05-2.11), kidney cancer (sumRR 36.12; 95% CI 1.70-16.00), brain cancer (sumRR 2.53; 95% CI 1.27-7.07) and leukaemia (sumRR 2.87; 95% CI 1.43-5.14). After 40 years employment risks for mortality from colon cancer were (sumRR 4.71; 95% CI 2.03-9.27), kidney cancer (sumRR 36.2; 95% CI 4.03-120.42) and bladder cancer (sumRR 5.7; 95% CI 1.56-14.33).	++	Youakim (2006) identified 14 papers (excluding overlapping cohorts), focussing on mortality, either from specific cohorts or from population mortality studies. Collectively, these papers yielded a summed Risk Ratio of 1.09 (0.92-1.25) with a marginally higher ratio for cohort studies alone (1.14, 0.90-1.41). For incidence/morbidity studies, six papers yielded a summed Risk Ratio of 1.39 (0.90-2.05), slightly lower for the three cohort studies (1.25, 0.68-2.10). However, the author does find that, combining studies utilising years of employment as a surrogate for exposure, yields a combined Risk Ratio of 2.53 (1.17-7.07) for 30 or more years of employment.

3.2.20 Thyroid Cancer

Relatively few papers were identified which examined the risk of thyroid cancer amongst firefighters. Figure 16 presents the risk estimate from those papers identified. In addition to the two papers based on the Florida cohort, three other papers were identified. Ma *et al* (2005) reported a significantly elevated risk of mortality amongst male firefighters in Florida (4.82, 1.30-12.3) and significantly elevated risks for morbidity amongst the same cohort for both males (1.77, 1.08-2.73) and females (3.97, 1.45-8.65). The three further studies all reported relative risks close to one, with two out of the three reporting risks less than one.

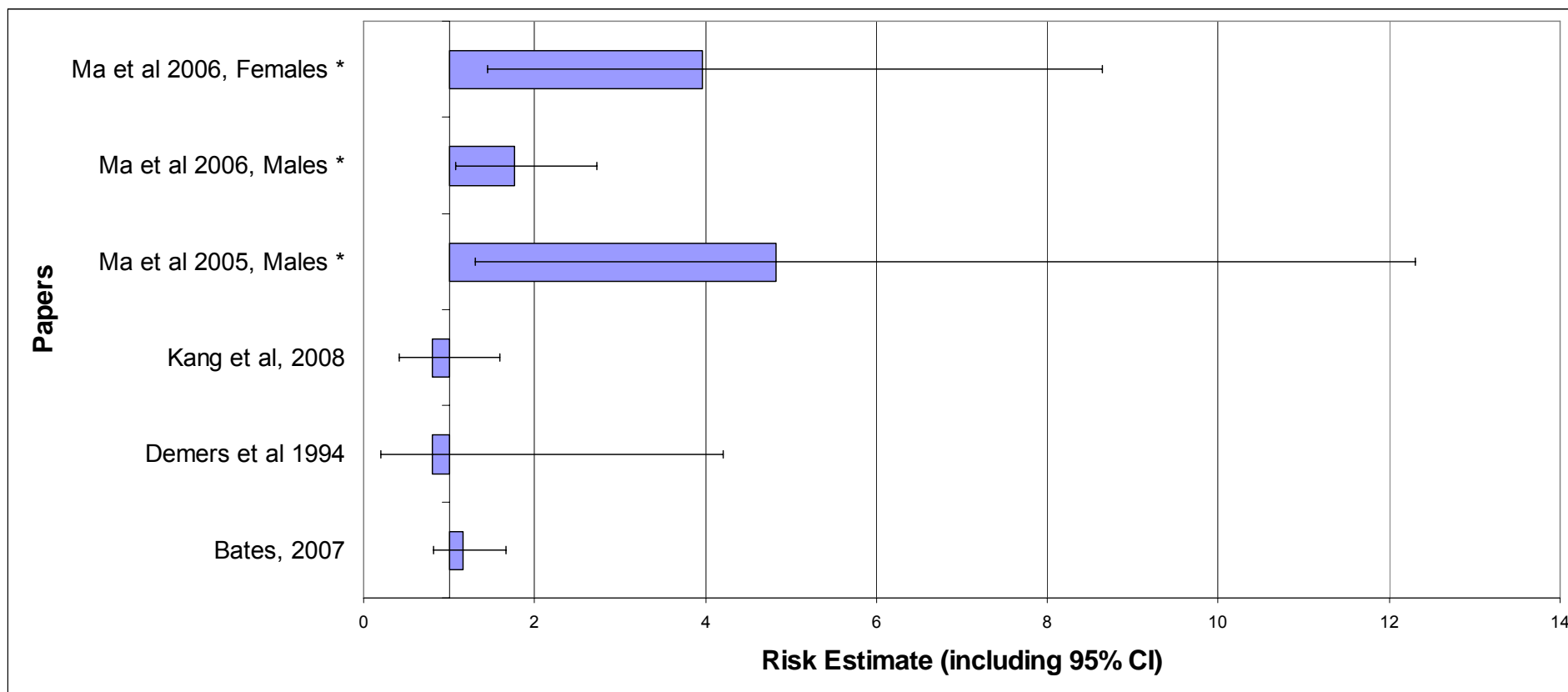
Ma *et al* (1998) also included thyroid cancer in their earlier study of mortality amongst white and black firefighters. However, although they reported a slightly elevated risk within the white cohort (MOR=1.3), this was based on only three deaths and no confidence interval was reported. There is clearly therefore no consistent evidence to suggest any occupational relationship between firefighting and thyroid cancer.

Of the five papers, three presented an estimate of person-years of follow-up (or equivalent). These totalled 945,688 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

As with some other cancers referred to earlier, the elevated risk of cancer morbidity amongst female firefighters, compared to their male counterparts, is a cause of some concern given the growing number of female firefighters in the UK. This study was based on an estimated 17,548 person-years of follow-up.

No reviews considered this form of cancer.

Table 16 summarises the data relating to firefighting and thyroid cancer.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 8: Comparisons of relative risks (with 95% confidence intervals) for thyroid cancer, derived from published studies

Table 16. Evidence relating Fire Fighting and Thyroid Cancer

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Bates 2007	Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).	+	The occupation of fire-fighting was not significantly associated with thyroid cancer (Odds Ratio=1.17, 0.82–1.67), based on 32 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988–1995 and 1996–2003. This yielded an excess in both sub-cohorts neither of which were statistically significant: 1988–1995: OR=1.54 (0.86–2.76); 1996–2003: OR=1.15 (0.67–1.98) although neither of these were significant.
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. Comparison group was 1878 police officers. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1–1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6–2.7) and ocular melanoma (SIR=5.2; CI 0.6–18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7–1.6) was slightly elevated compared to the general population.	++	Thyroid cancer had an SIR=0.8 (0.2–4.2) based on 1 death. This form of cancer was not included in analyses by duration of exposed employment or years since first employment.

Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Cancer of the thyroid yielded an SMOR=0.81 (0.41-1.59) based on 10 registrations. Indications of a trend were apparent in the age-stratified data, although none of the estimates were statistically significant and there were no deaths in the oldest sub-cohort.: 18-54: SMOR=0.56 (0.18-1.71); 55-74: SMOR=1.66 (0.36-7.64); 75.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, thyroid cancer had an MOR=1.3. There were insufficient deaths (3) for a confidence interval to be computed. For black firefighters there were no deaths from thyroid cancer.

Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	Four deaths from thyroid cancer amongst the male cohort yielded a statistically elevated SMR=4.82 (1.30-12.3). No deaths from this cancer were recorded amongst the female cohort. A subsidiary analysis of three deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave a very similar outcome with SMR=4.76 (0.96-13.9) which was not statistically significant.
Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	Twenty registered cases of thyroid cancer amongst the male cohort yielded a significantly elevated SIR=1.77 (1.08-2.73). Six cases of this cancer were recorded amongst the female cohort which again gave a significantly elevated risk estimate SIR=3.97 (1.45-8.65).

3.2.21 Lymphatic and Haemopoietic Cancers

Although many studies separated this group of cancers into their component parts (e.g. Lymphosarcoma; Hodgkin's disease; leukaemia) a small number either reported them collectively, or reported them individually and collectively. Grouping them clearly has the merit of enlarging the number of incident cases (or mortalities) to be used in deriving any risk estimate, although clearly any estimate will be biased towards any more commonly occurring forms and any differences in possible causal factors will be masked. However, as it is likely that any external (occupational) factor will have a similar influence on any form of cancer in such a group this might be of less importance.

Eight papers were identified which presented data in this category, the most recent being published in 1994. These are presented in Figure 17. They reveal an inconsistent pattern with three papers showing a positive association (the largest being the mortality study published by Eliopoulos *et al* (1984) which showed an SMR of 1.88 (0.39-5.50) based on three deaths). In contrast, the significant positive association reported in the mortality study of Burnett *et al* (1994) was based on 169 deaths (PMR=130, 111-151). In contrast, Vena and Fiedler (1987) reported an almost halved risk (0.55, 0.18-1.29) although this mortality study included only five deaths whilst that by Tornling *et al* (1994) (44, 9-127) was derived from just three deaths. As an aside, it is assumed that the listing of ICD codes in this paper as 200-209 is incorrect as there is no 209 code assigned.

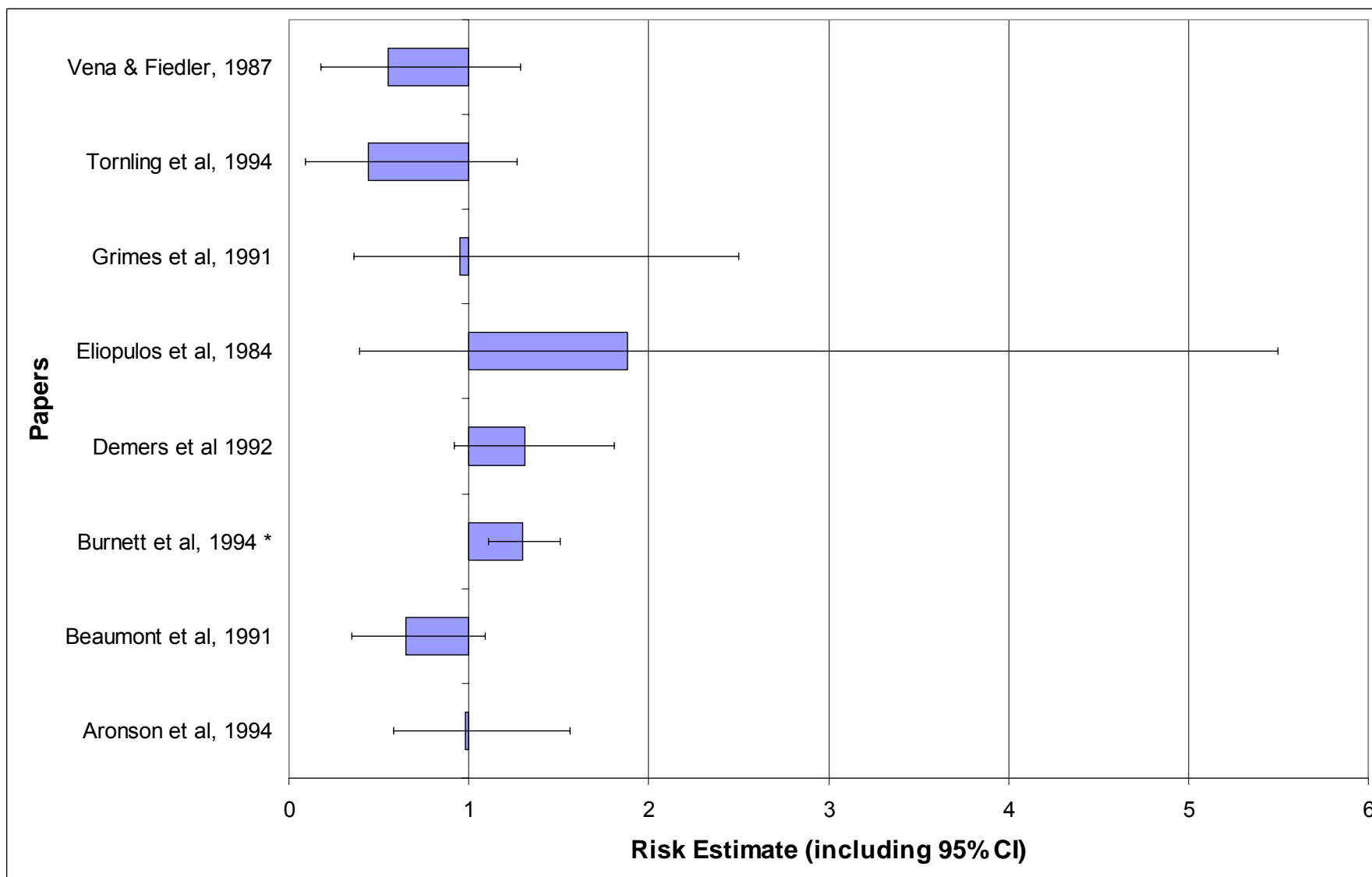
Clearly, given the limited number of generally small conflicting studies, there is no consistent picture emerging to suggest any apparent trend amongst firefighters.

Of the eight papers, five presented an estimate of person-years of follow-up (or equivalent). These totalled 311,816 person-years.

Given the dearth of studies, it is not surprising that few other authors have chosen to review these cancers as a group. The one exception is Guidotti (1995). The author excludes the papers providing source material from the main evidence table although citing them as Guidotti (1993); Demers *et al* (1992a); and Heyer *et al* (1990). This latter paper is a subsidiary paper to that of Demers *et al* (1992a), being limited to Seattle firefighters (1945-1983) whilst Demers *et al* (1992a) included Seattle, Portland and Tacoma firefighters over essentially the same period (1945-1989). They should not therefore be counted as separate studies. It is not clear why the author does not include values from other papers cited in the references to the review such as Beaumont *et al* (Risk Ratio=0.65, 0.35-1.09) and Vena and Fiedler (Odds Ratio=0.55, 0.18-1.29).

Whatever the reasons for inclusion, the SMRs of 1.26 (Heyer *et al*, 1990) and 1.40 (Demers *et al*, 1992a) when compiled into an 'aggregate' score, yield an approximate risk magnitude of 200, with the author concluding likely causation against the legal (civil) criterion. Clearly, this conclusion would appear to be unreliable and there is no consistent evidence to suggest anything more than a possibly modest positive association (1.1-1.2) between lymphatic and haemopoietic cancers and firefighting.

Table 17 presents the data relating to firefighting and lymphatic and haemopoietic cancers.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 17: Comparisons of relative risks (with 95% confidence intervals) for lymphatic and haemopoietic cancers, derived from published studies

Table 17. Evidence relating Fire Fighting and Lymphatic and Haemopoietic Cancers

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were 18 deaths attributed to lymphatic and haemopoietic cancers (ICD 9, 200-208) in the cohort, yielding a non-significant SMR of 98 (58-156). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of these deaths.

Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Clearly, prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for lymphatic and haemopoietic cancers was lower than 1.0, but not significantly (0.65, 0.35-1.09), based on 14 deaths. Exposure-related data was not reported for these cancers.
Burnett <i>et al.</i> , 1994	Assessment of mortality rates for firefighters using information from 27 USA states between 1984-1990. In total 5,744 deaths in white male firefighters were reviewed and analysis was based on proportionate mortality ratios comparing deaths from specific causes as compared to all causes in firefighters. The study identified there was increased levels of: malignant neoplasms (PMR=110; 95% CI 106-114); rectal cancer (PMR=148; 95% CI 105-205); skin cancer (PMR=163; 95% CI 115-223); kidney cancer (PMR=144; 95% CI 108-189); lymphatic and haematopoietic cancers (PMR=130 95% CI 111-151); and multiple myeloma (PMR=148; 95% CI 102-207).	++	The study identified a significantly increased level of lymphatic and haemopoietic cancers (PMR=130; 111-151).

Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Lymphatic and haemopoietic cancers had an SMR=1.31 (0.92-1.81) based on 37 deaths. An analysis by duration of exposed employment showed signs of a trend, with an elevated risk in the longest-serving cohort statistically significant: <10years: SMR=0.91 (0.2-2.3); 10-19 years: SMR=1.46 (0.06-3.0); 20-29 years: SMR=1.06 (0.6-1.8); > 30 years: SMR=2.05 (1.1-3.6). A similar analysis by years since first employment again showed a significant excess in the oldest sub-cohort: <20 years: SIR=1.65, (0.7-3.2); 20-29 years: SIR=0.39, (0.1-1.4); 30+ years: SIR=1.48 (1.02-2.0). Finally, the authors analysed the data by age at risk, which showed the oldest sub-cohort to be at a significantly increased risk: 18-39 years old: SMR=1.74 (0.6-4.1); 40-64 years old: SMR=0.96 (0.5-1.6); >65 years old: SMR=1.61 (1.0-2.5).
Eliopoulos <i>et al</i> 1984	973 fire fighters employed by the Western Australian Fire Brigade between 1 October 1939 and 31 December 1978 were successfully followed up to 31 December 1978. Mortality from all causes was less than expected (SMR=0.80, 0.67 to 0.96). No specific causes of death attained statistical significance and there were no indications that mortality was associated with duration of employment.	++	The SPMR for lymphatic and haemopoietic cancers, based on three deaths, was 1.88 (0.39-5.50). There was no sub-cohort analysis of these deaths reported.
Grimes <i>et al</i> 1991	A twenty year Proportionate Mortality study was conducted with all male firefighters in the City of Honolulu from 1969-1988 who had at least one year of service. This covered 205 deaths. Significant increases in risk of death were found for brain cancer (ICD 9, 191-192) (PMR=3.78, 1.22-11.71); prostate cancer (ICD 9 185) (PMR=2.61, 1.38-4.97); and cirrhosis of the liver (ICD 9 571) (PMR=2.3, 1.21-4.37). It was suggested that the latter could, at least in part, be attributed to an excess of alcohol consumption in this group. A significant decrease in mortality was observed for respiratory diseases (ICD 9 460-519) (PMR=0.37, 0.17-0.81).	+	The PMR for cancers of the lymphatic system (ICD 9, 200-209) was 0.95 (0.36-2.50) based upon 4 deaths. A subsidiary analysis for firefighters of Caucasian or Hawaiian extraction yielded values of 0.66 (0.09-4.63) and 0.97 (0.24-3.84) based upon one and two deaths respectively.

Guidotti, 1995	Reviews studies of mortality in firefighters. Appears to have included all the main studies identified elsewhere but fails to describe process of identifying and selecting papers. Text summarises major findings and table presents SMR (or PMR) values and confidence intervals. Overall summary table presented as the approximate magnitude of any associations as 100, 150 or 200, presumably signifying relative risk (base 100). These seem to be based upon an interpretation of the accumulated evidence but the method of their derivation is not given. Basis of selection for chosen outcomes to address is not given, described as "specific outcomes of interest". Not all outcomes referred to in text are covered in the final table. Thus, the text refers to genitourinary cancers (excluding bladder cancer) as "relatively uncommon cancers...and the risk appears to be high, close to or in excess of a doubled relative risk." Only bladder cancer data abstracted in study summaries and overall summary of associations.	-	The author does not present the papers relating to lymphatic and haemopoietic cancers although three are cited. The relative risks are described as "unusually high" although "small numbers of these relatively rare cancers make it difficult to evaluate the significance of the association in these studies. Despite these uncertainties, the author concludes that there is a likely causal association to which an approximate risk magnitude of 200 is assigned.
Tornling <i>et al.</i> 1994	An investigation of cancer incidence and mortality rates in Swedish firefighters. All male firefighters employed for at least one year in the City of Stockholm between 1931 and 1981 were traced. This resulted in 1,153 individuals but a further group were already deceased so the total sample size was 1,116 males. Exposure measures were made from a 10% sample of fire reports, developed into an exposure index for each calendar year and each fire station. Standardised mortality ratios were calculated. Overall mortality was lower than expected (SMR=82; 72-91). The cancer incidence was equal to expected but increased stomach cancer was observed (SMR=192; 114-304) and brain cancer (SMR 496; 135-270).	++	Three deaths from all haemopoietic cancers (ICD 9, 200-209) resulted in an SMR=44 (9-127). The same number of recorded cases gave a lower morbidity ratio which was significantly less than 1.0: SMR=32, 6-92. No further analyses of these cancers were reported.
Vena and Fiedler, 1987	A mortality study of all full-time municipal employees of Buffalo USA for a minimum of 5 years between 1950 and 1979. Individuals who had worked at least one year as a firefighter were included. This covered 1,867 white male firefighters, including 890 currently employed, 740 retirees, 65 who had resigned and 172 who died in service. The analysis identified that firefighters had significantly more benign neoplasms (SMR=4.17; 1.34-9.73), malignant neoplasms including colon cancer (SMR=1.83; 1.05-2.97), and bladder cancer (SMR=2.86; 1.30-5.40).	++	Five deaths from lymphatic and haemopoietic cancers (ICD 9 200-209) amongst the cohort yielded an SMR= 0.55(0.18-1.29). These forms of cancer did not feature in subsidiary analyses of firefighters with estimates of exposure.

3.2.22 Hodgkin's Disease

Again, relatively few papers were identified which addressed Hodgkin's lymphoma, although some have included it within the general category of lymphatic and haemopoietic tissue, which would encompass lymphosarcoma (non-Hodgkin's lymphoma) and leukaemia. Figure 18 shows the risk estimates obtained from the papers identified.

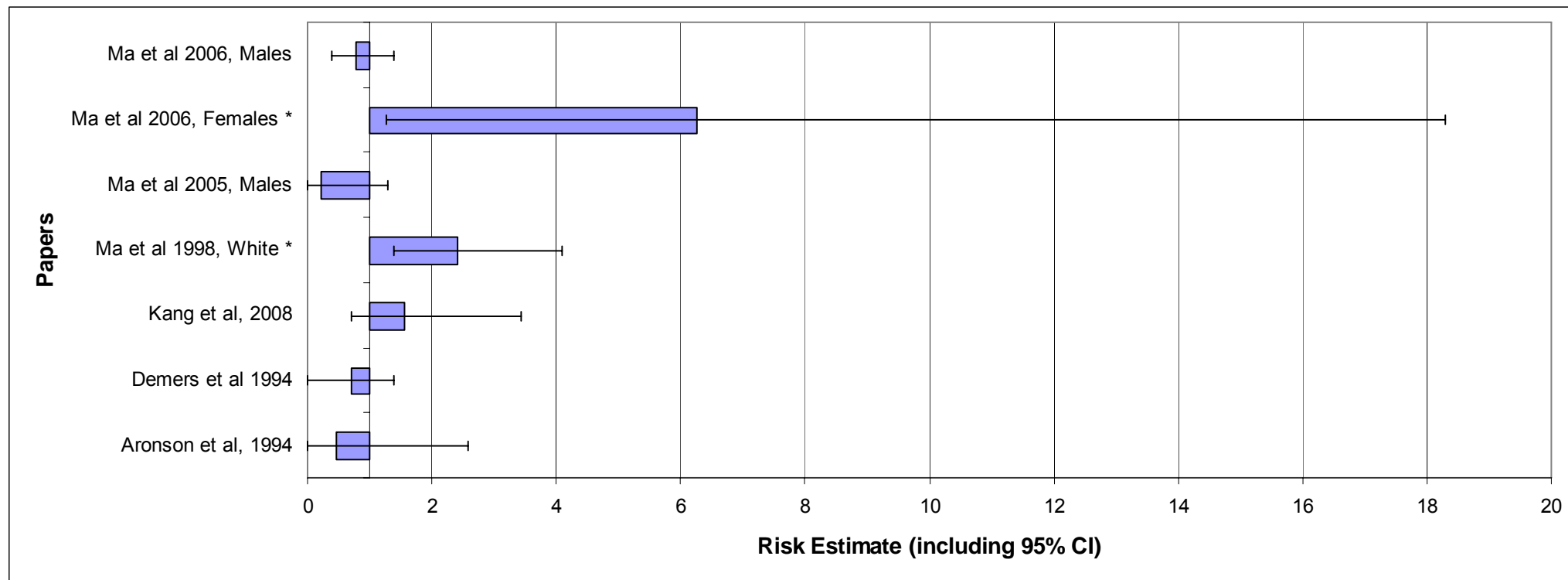
Three papers by Ma and colleagues (two mortality and one morbidity) and three others (two morbidity and one mortality) are presented. Only one study of male firefighters (Ma *et al*, 1998) identified a significantly elevated risk (MOR=2.4, 1.4-4.1) although this is not repeated in the later mortality (Ma *et al*, 2005) or morbidity (Ma *et al*, 2006) studies by the same authors with a different cohort, nor by the other studies reported. Thus, there is no consistent evidence to suggest any elevation of risk of Hodgkin's disease amongst male firefighters.

As with thyroid cancer, morbidity study of female firefighters by Ma and co-workers (2006) showed a considerably increased risk (SIR=6.25, 1.26-18.30) although it was based on relatively few cases (derived from an estimated 18,843 person-years of follow-up) and was not also reflected in the mortality study on the same cohort. Once again however it does suggest the need for particular scrutiny of the health of female firefighters in future years.

Of the six papers, four presented an estimate of person-years of follow-up (or equivalent). These totalled 1,059,696 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

No reviews considered this cancer.

Table 18 summarises the evidence relating to firefighting and Hodgkin's Disease.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 18: Comparisons of relative risks (with 95% confidence intervals) for Hodgkin's Disease, derived from published studies

Table 18. Evidence relating Fire Fighting and Hodgkin's Disease

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97). This effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There was 1 death attributed to Hodgkin's Disease (ICD 9, 201) in the cohort, yielding a non-significant SMR of 47 (1-259). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of this death.
Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Hodgkin's Disease had an SIR=0.7 (0.0-4.1) based on 1 death. No analyses by exposure variables were reported.

Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This included 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 1.04-1.79) and brain cancer (SMOR 1.9; 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Hodgkin's Disease yielded an SMOR=1.56 (0.71-3.43) based on 8 registrations. A trend for reducing risk with age was apparent in the age-stratified data: 18-54: SMOR=2.86 (0.76-10.74); 55-74: SMOR=1.27 (0.30-5.47); 75+: SMOR=0.91 (0.06-15.21).
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white and 66 black firefighters. Using a database of 24 states from 1984-1993, mortality odds ratios were calculated for both groups. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 1.1-1.2), lip (MOR=4.9; 1.9-18.3), pancreas (MOR=1.2; 1.0-1.5), bronchus and lung (MOR=1.1; 1.0-1.2), soft tissue sarcoma (MOR =1.6; 1.0-2.7), melanoma (MOR=1.4; 1.0-1.9), prostate (MOR=1.2; 1.0-1.3), kidney and renal pelvis (MOR=1.3; 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 3.0-16.0), colon cancer (MOR=2.1; 1.1-4.0), prostate cancer (MOR=1.9; 1.2-3.2) and nasopharynx (MOR=7.6; 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, Hodgkin's Disease had a significantly elevated risk estimate: MOR=2.4 (1.4-4.1), based on 13 deaths. There were no deaths from this cancer amongst the cohort of black firefighters.
Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	One death from Hodgkin's Disease amongst the male cohort yielded an SMR=0.23 (0.00-1.30). No deaths from this cancer were recorded amongst the female cohort. There were no deaths from this cancer amongst the firefighters with the longest estimated exposure (registered 1972-1976).

Ma <i>et al.</i> , 2006	<p>A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.</p>	++	<p>Eleven registered cases of Hodgkin's Disease amongst the male cohort yielded a SIR=0.77 (0.38-1.38). Three cases of this cancer were recorded amongst the female cohort yielding a significantly elevated morbidity estimate (SIR=6.25, 1.26-18.30).</p>
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3.2.23 Non-Hodgkin's Lymphoma (Lymphosarcoma)

Thirteen papers were identified which addressed non-Hodgkin's Lymphoma or Lymphosarcoma. Diagnostic categories were not always consistent as, for example, some restricted their analysis to cancers within ICD 9 code 200 whilst others clustered this with code 202. In addition, five reviews considered any possible association between these cancers and being a firefighter.

Figure 19 illustrates the main findings from the primary papers. These show that a majority of papers (ten) found an increased risk, although in only two of these did this increase attain statistical significance. In one paper Aronson *et al.*, 1994 the risk estimate (SMR) marginally exceeded 2 (2.04) although the very wide confidence interval (42-596) indicates a need for caution in interpreting this. Three papers found a more modest decrease in risk, again with none attaining significance. These collectively appear to suggest that there probably is a modest increase in risk, although this cannot be stated with any certainty.

One study Ma *et al.*, 2006 studied the incidence of non-Hodgkin's Lymphoma amongst female firefighters. The paper reported a markedly elevated SIR of 33.30. However, as this was based on one observed case and was bounded by a large confidence interval (0.44-185.00) no particular emphasis should be placed on this finding.

Of the 13 papers, six presented an estimate of person-years of follow-up (or equivalent). These totalled 1,387,369 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al.* 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

Non-Hodgkin's Lymphoma did not feature in the cancers which Golden *et al* (1995) chose to describe in detail. However, the authors state that 'without exception' the studies identified reported marked increases in risk. The authors cite five sources, choosing three of these to focus on, two of which found a risk more than double that of the general population whilst the third, Sama *et al* (1990), only found this in comparison to police officers. As can be seen from figure 5, the comparison by Sama and colleagues with the general population identified a smaller, non-significant increase.

The findings of Guidotti, 1995 are difficult to interpret, as this author clusters lymphatic and haemopoietic cancers together.

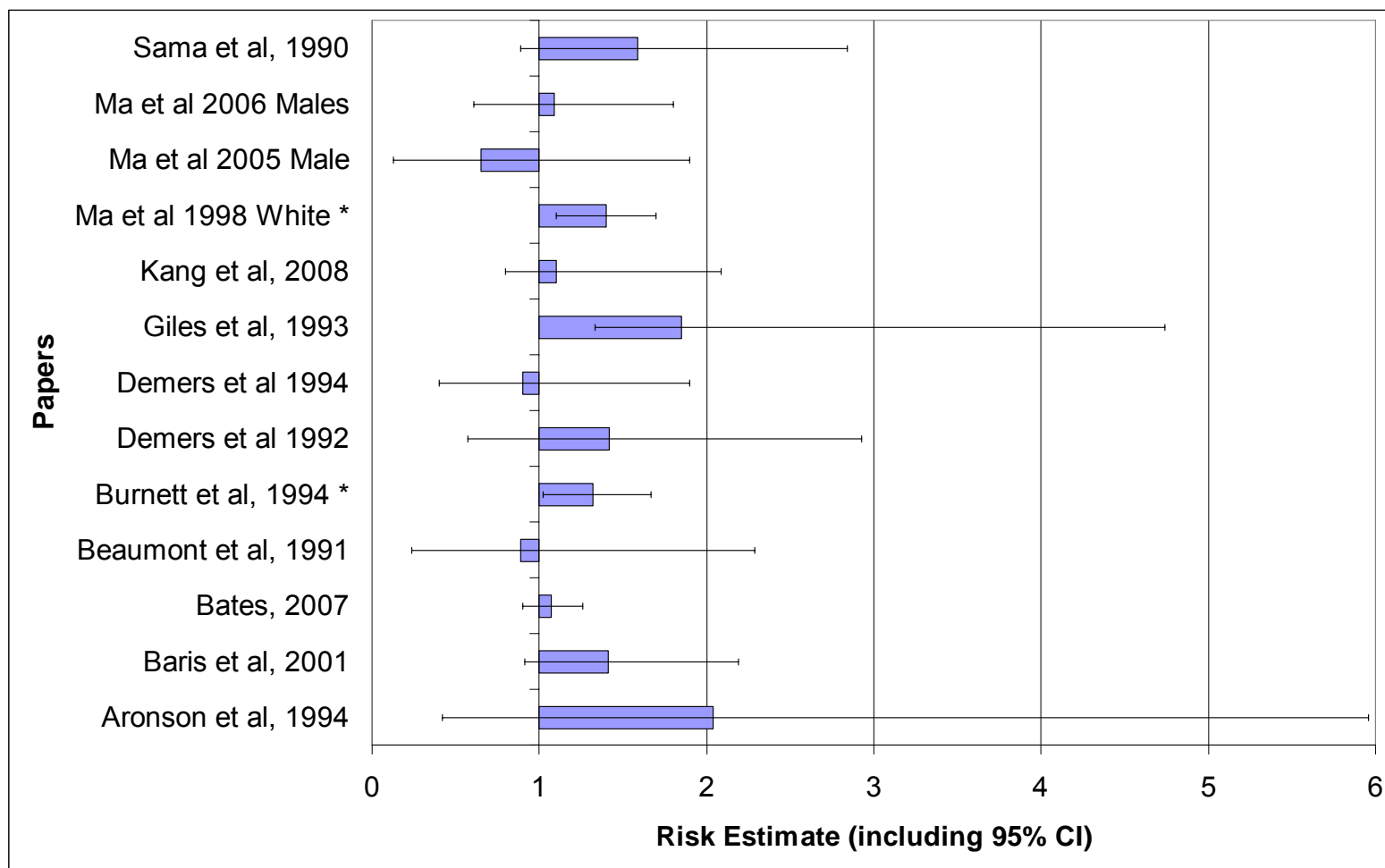
LeMasters *et al* (2006) utilised eight studies in deriving a summary risk estimate of 1.51 (1.31-1.73), seven of which are included in the present review. Those excluded encompass the three more recent papers by Ma *et al* (2006), Bates (2007) and Kang *et al* (2008); the mortality study by Ma *et al* (2005) and the 1994 paper by Demers and co-workers which they considered overlapped with the earlier paper by the same authors. Accepting that caveat, (and the overlap in the cohort for the mortality and morbidity papers by Ma and colleagues) the remaining omitted papers would have reduced the risk estimate and possibly also increased the uncertainty of the estimate.

Youakim (2006) utilised eight mortality studies in deriving a summed risk ratio for all studies of 1.40 (1.20-1.60). However, when the analysis was reduced to cohort studies only, the summed risk estimate was reduced and ceased to be statistically significant (1.25, 0.88-1.72). Using incidence or morbidity studies also yielded lower, non significant summed risk estimates with values of 1.34 (0.36 - 1.97) for all studies and 1.11 (0.55 - 1.99) for cohort studies.

Finally, according to Straif *et al* (2007), their update of the review by LeMasters and co-workers (2006) identified increased risks in five of the six studies taken into account with an average relative risk of 1.2. Although no confidence interval is given, the authors describe this risk ratio as significantly increased. However, it is not known whether their deliberations and calculations included the papers by Bates (2007) and Kang *et al* (2008) which would have reduced the estimated risk still further.

In conclusion, although early studies and reviews appeared to suggest a marked increase in risk of a diagnosis of non-Hodgkin's Lymphoma amongst firefighters, further, more recent studies have progressively suggested a diminution of that risk, such that current estimates would be less than a 20% increase with some uncertainty as to whether that figure would be statistically significant. The isolated finding of an elevated risk amongst female firefighters, although statistically highly unreliable, adds further weight to the argument for particular scrutiny in future years of the slowly growing numbers of female firefighters in the UK.

Table 19 presents the data relating to firefighting and Non-Hodgkin's Lymphoma.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 19: Comparisons of relative risks (with 95% confidence intervals) for non-Hodgkin's Lymphoma, derived from published studies

Table 19. Evidence relating to Fire Fighting and Non-Hodgkin's Lymphoma (Lymphosarcoma)

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There were 3 deaths attributed to non-Hodgkin's Lymphoma (Lymphosarcoma) (ICD 9, 200) in the cohort, yielding a non-significant SMR of 204 (42-596). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of these deaths.

- Baris *et al.*, 2001 Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations. ++
- Bates 2007 Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33). +

20 deaths attributed to non-Hodgkin's Lymphoma (Lymphosarcoma) (ICD 9, 200, 202) yielded a non-significant SMR of 1.41 (0.91-2.19). In the analysis of duration of employment as a surrogate for exposure there was no linear trend across the three categories: (≤ 9 years, SMR=1.47 (0.66-3.26); 10-19 years, SMR=1.03, (0.43-2.47); ≥ 20 years, SMR=1.72; 0.90-3.31). As an alternative measure of exposure, those who were in ladder companies only were more likely to die from non-Hodgkin's Lymphoma although none of the estimates were significant. (engine company: SMR=1.64, (0.85-3.15); ladder company: SMR=2.65 (0.86-8.23); both ladder and engine companies: SMR=1.11, (0.55-2.21)). Those recruited during 1935-1944 were at a significantly elevated risk of death from non-Hodgkin's Lymphoma although this did not seem to be part of any systematic trend: (pre-1935: SMR=0.72 (0.23-2.22); 1935-1944: SMR=2.19, (1.18-4.07); post 1944: SMR=1.29, (0.62-2.70)).

The occupation of fire-fighting was not significantly associated with non-Hodgkin's Lymphoma (Lymphosarcoma) (Odds Ratio=1.07, 0.90–1.26), based on 159 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988-1995 and 1996-2003. This did not yield any particular trends: older registrants OR=1.03 (0.74-1.43) and younger registrants OR=0.94 (0.67-1.32).

Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; CI 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for non-Hodgkin's Lymphoma (Lymphosarcoma) was slightly below 1.0, but not significantly (0.89, 0.24-2.29), based on 4 deaths. No exposure-related data for this cancer was reported.
Burnett <i>et al.</i> , 1994	Assessment of mortality rates for firefighters using information from 27 USA states between 1984-1990. In total 5,744 deaths in white male firefighters were reviewed and analysis was based on proportionate mortality ratios comparing deaths from specific causes as compared to all causes in firefighters. The study identified there was increased levels of malignant neoplasms (PMR=110; 106-114), rectal cancer (PMR=148; 105-205). skin cancer (PMR=163; 115-223); kidney cancer (PMR=144; 108-189), lymphatic and haematopoietic cancers (PMR=130 111-151) and multiple myeloma (PMR=148; 102-207).	++	The study identified an significantly elevated risk of Non-Hodgkin's Lymphoma (Lymphosarcoma) (PMR=132, 102-167),
Demers <i>et al.</i> , 1992a	A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. At follow-up for 4401 firefighters, 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population. However, an excess of brain cancers was identified (SMR=2.09; 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 1.1-3.6) and leukaemia (SMR=2.6; 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.	++	Non-Hodgkin's Lymphoma (Lymphosarcoma) had an SMR=1.42 (0.57-2.93) based on 7 deaths. This cancer did not feature in any of the analyses for surrogates of exposure.

Demers <i>et al.</i> , 1994	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Non-Hodgkin's Lymphoma (Lymphosarcoma) had an SIR=0.9 (0.4-1.9) based on 7 reported cases. An analysis by duration of exposed employment showed no particular pattern: <10 years: 0.9 (0.0-4.9); 10-19 years: 0.6 (0.0-3.5); 20-29 years: 1.2 (0.4-2.7); 30+ years: 0.0 (0.0-5.8). A similar analysis by years since first employment showed a trend for those to have been employed for less time to be more likely to be diagnosed with non-Hodgkin's Lymphoma: <20 years: SIR=1.9 (0.2-6.7); 20-29 years: 0.7 (0.0-3.7); SIR=30+ years: SIR=0.8 (0.2-2.0).
Giles 1993	This paper describes the incidence of cancer between 1980-1989 in a cohort of 2,865 male firefighters employed in Melbourne, Australia between 1917 and 1989. The comparison group was the population of the state of Victoria. A total of 50 cancers were registered amongst the cohort, which did not yield a SIR significantly different from the general population. Ten named groups of cancers were described, none of which gave incidences significantly different from 1.0. There were significantly elevated incidences of "all cancers" and cancers of the colon and rectum amongst the older sub-cohort ≥ 65 years: all cancers: 2.14, (1.32-2.37); colorectal cancers: 3.65, (1.13-7.14). Neither time since start of employment or duration of employment resulted in any incidences significantly different from the comparison population.	++	Four registered case of Non-Hodgkin's Lymphoma (Lymphosarcoma) gave a SIR=1.85, (0.50-4.74).
Golden <i>et al</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain,; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	Non-Hodgkin's Lymphoma did not feature in the cancers which the authors chose to describe in detail. However, the authors state that 'without exception' the studies identified reported marked increases in risk. No summary risk estimate is presented.

Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Non-Hodgkin's Lymphoma (Lymphosarcoma) yielded an SMOR=1.10 (0.58-2.09) based on 13 registrations. No trend was apparent in the age-stratified data: 18-54: SMOR=1.18 (0.26-5.36); 55-74: SMOR=0.83 (0.23-2.96); 75+: no registered cases.
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The authors concluded that there probably was an association between firefighting and non-Hodgkin's Lymphoma. The meta-analysis across all forms of study, utilising a total of 8 analyses, yielded a significant Summary Risk Estimate of 1.51 (1.31 –1.73) for non-Hodgkin's Lymphoma. This was slightly higher than the meta-SMR and PMR of 1.36, (1.10-1.67) and the heterogeneity of the data was not significant at the 10% level.
Ma <i>et al.</i> , 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, non-Hodgkin's Lymphoma (Lymphosarcoma) had an MOR=1.4 (1.1-1.7), based on 76 deaths. For black firefighters the MOR was 0.8 from one death, which did not permit a confidence interval to be computed.

Ma <i>et al.</i> , 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	Three deaths from Lymphosarcoma amongst the male cohort yielded an SMR=0.65 (0.13-1.90). No deaths from this cancer were recorded amongst the female cohort. A subsidiary analysis of three deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave a slightly higher risk with SMR=0.94 (0.19-2.76).
Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	15 registered cases of non-Hodgkin's Lymphoma (Lymphosarcoma) amongst the male cohort yielded a SIR=1.09 (0.61-1.80). One case of this cancer recorded amongst the female cohort gave an SIR=33.30 (0.44-185.00).
Sama <i>et al.</i> , 1990	A study using cancer registry data from Massachusetts in the USA. Samples included 315 male cancer cases between 1982 and 1986; 392 male white police officers and 29,277 State cases. The analysis included SMORS and it was identified that there was an elevated risk of melanoma (SMOR=292; 95% CI 170-503), bladder cancer (SMOR 159; 95% CI 107-414) for firefighters compared to State residents. In comparison with police officers, there was an increase risk in bladder cancer (SMOR=211; 95% CI 107-414) and non-Hodgkin's Lymphoma (SMOR=32; 95% CI 119-898). A number of difficulties with the study were identified by the researchers including the potential for underreporting of cancers.	++	A non-significant but elevated risk of non-Hodgkin's Lymphoma was calculated from 14 registered cases (SMOR=327, 89-284).

(Straif *et al.*, 2007) Update of a previous meta-analysis by IARC. Identified that testicular cancer showed increased risk in firefighters (average RR 1.5), prostate cancer was also increased with an average RR of 1.3. Non-Hodgkin's Lymphoma was increased with an average RR of 1.2. Study stated on the basis of limited evidence that exposure as a firefighter is possible carcinogenic to humans (Group 2B) ++

Youakim, 2006 An analysis of 16 studies to identify risk of cancer among firefighters. The study identified an increase in risk of kidney cancer (sumRR 1.25; 95% CI 1.02-1.43) and non-Hodgkin's Lymphoma (sumRR 1.4; 95% CI 1.20-1.60). Further analysis using a sub-cohort of studies was also made based on duration of employment with 30 years or more as a firefighter had an increased risk for colon cancer (sumRR 1.51; 95% CI 1.05-2.11), kidney cancer (sumRR 36.12; 95% CI 1.70-16.00), brain cancer (sumRR 2.53; 95% CI 1.27-7.07) and leukaemia (sumRR 2.87; 95% CI 1.43-5.14). After 40 years employment risks for mortality from colon cancer were (sumRR 4.71; 95% CI 2.03-9.27), kidney cancer (sumRR 36.2; 95% CI 4.03-120.42) and bladder cancer (sumRR 5.7; 95% CI 1.56-14.33). ++

Identified that non-Hodgkin's Lymphoma (Lymphosarcoma) showed an increased risk in firefighters with an average RR of 1.2.

Eight mortality studies yielded a significantly elevated summed risk ratio for all studies of 1.40 (1.20-1.60). However, when the analysis was reduced to cohort studies only, the summed risk estimate was reduced and ceased to be statistically significant (1.25, 0.88-1.72). Using incidence or morbidity studies also yielded lower, non-significant summed risk estimates with values of 1.34 (0.36 - 1.97) for all studies and 1.11 (0.55 - 1.99) for cohort studies.

3.2.24 Multiple Myeloma

As shown in Figure 20, the seven papers identified which present data on multiple myeloma again demonstrate a confused pattern, with two studies showing sizeable positive associations (Burnett *et al*, 1994, PMR=148, 102-207; Baris *et al*, 2001, SMR=1.68, 0.90-3.11), one of which was statistically significant; and a further study showing a larger negative association (Aronson *et al*, 1994, SMR=39, 1-215) although this latter finding was less convincing, being based on a single death in the cohort. In contrast, there were 66 and 10 deaths in the other two studies. The other noticeable negative association (Demers *et al*, 1994, SIR=0.7, 0.1-2.6) was based on just two incident cases. The more convincing findings would generally therefore seem to be these showing a positive association although one which, when the other less marked studies are taken into account, would almost certainly be less than 1.5.

Of the seven papers, only three presented an estimate of person-years of follow-up (or equivalent). These totalled 353,912 person-years.

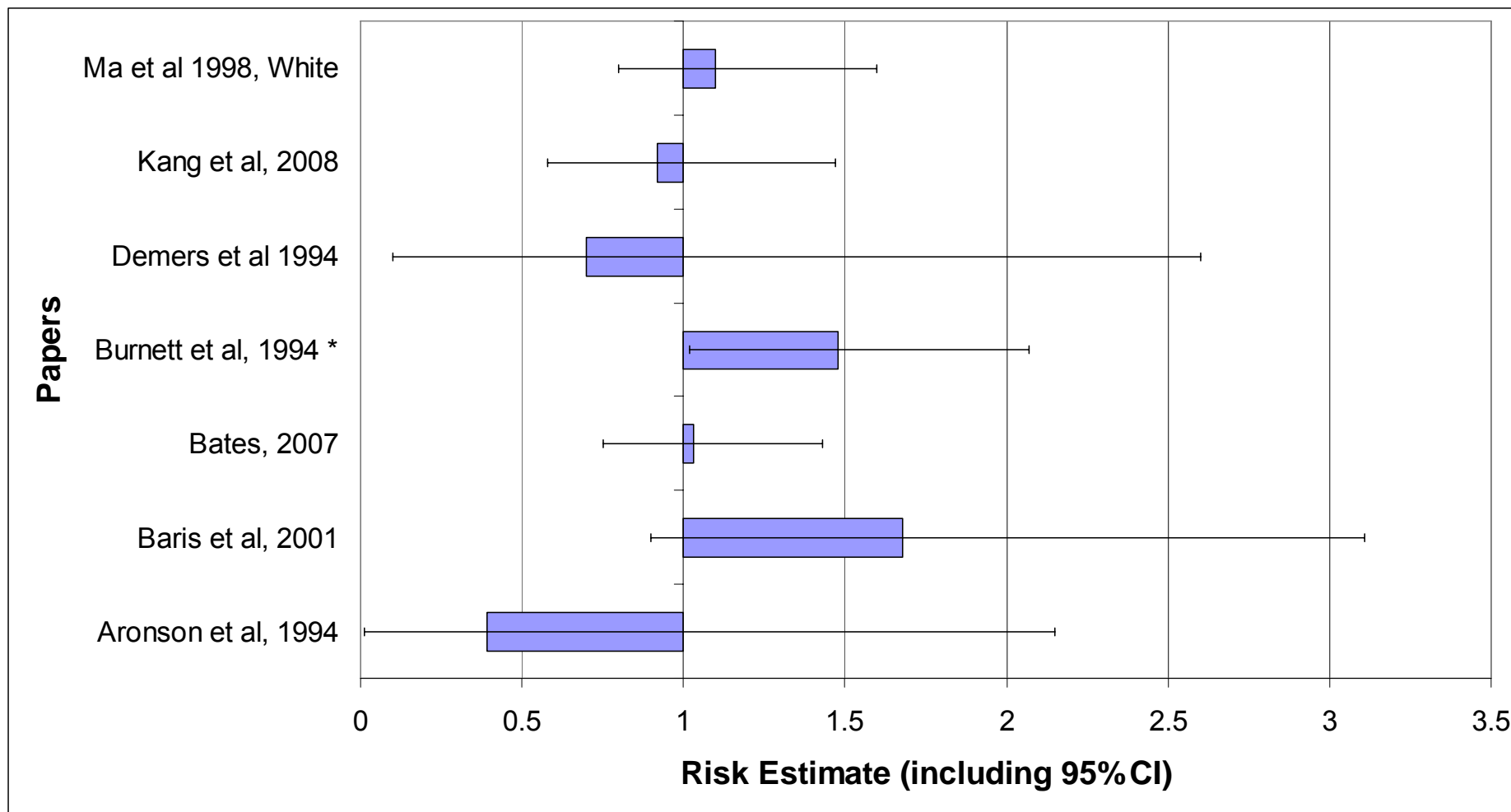
Three reviews considered any association between multiple myeloma and being a firefighter. Howe and Burch (1990) identified five primary studies which collectively reported a total of 19 deaths although one of these actually included some other lymphatic and haemopoietic cancers. The review authors calculated a summary Odds Ratio of 1.51 (0.91-2.35) from these studies, which were mainly population mortality studies.

Golden *et al* (1995) cited one of these studies, together with that by Burnett *et al* (1994) and the Howe and Burch review (which was described as largely based on unpublished reports). The common paper was that by Heyer *et al* (1990) which overlaps considerably with the Demers *et al* (1992a) cohort which was also cited. There is consequently some overlap within the material considered by Golden *et al* (1995). The authors do not derive any conclusion over any possible association although they do cite the Howe and Burch finding referred to above.

Multiple myeloma was one of the forms of cancer explored by LeMasters *et al* (2006), deriving a summary Risk Estimate of 1.53 (1.21-1.94) based on ten analyses. These encompassed the older studies identified by Howe and Burch (1990) together with most of those examined for this review (but clearly excluding the more recent studies of Bates (2007) and Kang *et al* (2008).

The method of calculation adopted by LeMasters *et al* (2006) means that the study of Burnett *et al* (1994) has a considerable influence because of the numbers of deaths. However, the studies by Bates (2007) (37 deaths) and Kang *et al* (2008) (29 deaths) are not insubstantial and will undoubtedly reduce any revised summary estimate of risk. This therefore reinforces the view that the most accurate estimate of risk is a positive association between firefighting and multiple myeloma with a risk ratio <1.5.

Table 20 summarises the evidence relating to firefighting and multiple myeloma.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 20: Comparisons of relative risks (with 95% confidence intervals) for multiple myeloma, derived from published studies

Table 20: Evidence relating to Firefighting and Multiple Myeloma

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	There was 1 death attributed to multiple myeloma (ICD 9, 203) in the cohort, yielding a non-significant SMR of 39 (1-215). Further analysis by years since first employment, as a surrogate for exposure, did not involve analysis of this death.

Baris <i>et al.</i> , 2001	<p>Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations.</p>	++	<p>Ten deaths attributed to multiple myeloma (ICD 9, 203) yielding a non-significant SMR of 1.68 (0.90-3.11). In the analysis of duration of employment as a surrogate for exposure there was a trend for an increasing risk across the three categories: ≤ 9 years, SMR=0.73 (0.10-5.17); 10-19 years, SMR=1.50., (0.48-4.66); ≥ 20 years, SMR=2.31 (1.04-5.16) with the value for the longest serving sub-cohort being statistically significant. As an alternative measure of exposure, those who were in ladder companies only were more likely to die from multiple myeloma: (engine company: SMR=1.64, (0.85-3.15); ladder company: SMR=2.65 (0.86-8.23); both ladder and engine companies: SMR=1.11, (0.55-2.21)). There was no particular pattern in the analysis based on hire year: pre-1935: SMR=0.72 (0.23-2.22); 1935-1944: SMR=2.19, (1.18-4.07); post 1944: SMR=1.29, (0.62-2.70) with the value for the middle sub-cohort being statistically significant.</p>
Bates 2007	<p>Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33).</p>	+	<p>The occupation of fire-fighting was not significantly associated with multiple myeloma (Odds Ratio=1.03, 0.75–1.43), based on 37 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988-1995 and 1996-2003. The older registrants were slightly more likely to develop multiple myeloma although neither risk estimate was significant older registrants: OR=1.85 (0.95-3.61); younger registrants: OR=1.41 (0.75-2.65).</p>

Burnett <i>et al.</i> , 1994	et	Assessment of mortality rates for firefighters using information from 27 USA states between 1984-1990. In total 5,744 deaths in white male firefighters were reviewed and analysis was based on proportionate mortality ratios comparing deaths from specific causes as compared to all causes in firefighters. The study identified there was increased levels of malignant neoplasms (PMR=110; 95% CI 106-114), rectal cancer (PMR=148; 95% CI 105-205), skin cancer (PMR=163; 95% CI 115-223), kidney cancer (PMR=144; 95% CI 108-189), lymphatic and haematopoietic cancers (PMR=130 95% CI 111-151) and multiple myeloma (PMR=148; 95% CI 102-207).	++	The study identified there was an increased risk of multiple myeloma (PMR=148, 102-207).
Demers <i>et al.</i> , 1994	et	A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. Comparison group was 1878 police officers. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 95% CI 1.1-1.7), as was stomach cancer (SIR 1.4; 95% CI 0.6-2.7) and ocular melanoma (SIR=5.2; CI 0.6-18.8). The risk of colon cancer (SIR=1.1; 95% CI 0.7-1.6) was slightly elevated compared to the general population.	++	Multiple myeloma had an SIR=0.7 (0.1-2.6) based on 2 deaths. Analyses by duration of exposed employment and by years since first employment did not include multiple myeloma.
Golden <i>et al.</i> 1995	et	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and summarised some of the research literature on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness in any case. Cancers summarised are: brain,; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	States that few studies had sample sizes sufficient to assess any risk of multiple myeloma in firefighters. Refers to four papers, two showing a reduced risk and two an increased risk. Cites another review Howe and Burch, 1990 as concluding that there was consistent evidence of a causal association but no summary risk estimate is presented in this review.

Howe and Burch, 1990	Review paper from 1990. Looked at 'all cancers' and "those specific cancers which individual studies have reported to show an association with the occupation of fire fighter". Lung, colon, brain, malignant myeloma and multiple myeloma were chosen. Studies with any demonstrable major bias were excluded (not listed). Note that much work on testicular cancer (e.g. early Bates <i>et al</i> study from 1995) would not be covered. Pooled estimate showed sig all cause reduced risk (0.92, 0.85-0.98) in SMR but increased (1.09, 1.01-1.17) PMR which authors dismiss as artefact of healthy worker effect. For lung cancer the pooled SMR/PMR values were 0.92/1.08, neither of which were sig. Pooling colon cancer studies again yielded non-sig effects (SMR, 1.12, PMR, 1.06). For brain tumours the pooled SMR of 1.43 and PMR of 1.45 narrowly missed sig (CI, 0.93-2.12 & 0.95-2.12 respectively). Authors point out that the main study unsupportive of an effect related primarily to pre-WW2 exposures when, it is hypothesised, exposures to carcinogens would have been less. No dose-response relationship has been seen but causation is seen as biologically plausible. Sig increased risk of malignant melanoma based on pooled estimate of 1.73 from 5 studies. Exposure-response relationship also seen. However, authors regard causal connection as implausible with high risk of confounding. For multiple myeloma, increased pooled risk of 1.51 is not sig. This value is distorted by high value (10.00) in 1 study.	+	The authors identified five papers in relation to multiple myeloma. They calculated a cumulative SMR of 1.51 (0.91-2.35). Bearing in mind this non-significant finding, the authors concluded that any conclusion must be tentative because of limited numbers of papers, but that there appeared to be some evidence of a positive association for multiple myeloma and that if such an association exists, a causal influence was at least plausible.
Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Multiple myeloma yielded an SMOR=0.92 (0.58-1.47) based on 29 registrations. No trend was apparent in the age-stratified data: 18-54: SMOR=0.68 (0.13-3.54); 55-74: SMOR=0.75 (0.32-1.74); 75+: SMOR=0.76 (0.17-3.36).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The authors concluded that there was a probable risk of a causal association between firefighting and multiple myeloma. The meta-analysis across all forms of study, utilising a total of 10 analyses, yielded a significant Summary Risk Estimate of 1.53 (1.21 –1.94) for multiple myeloma. This was consistent with the meta-SMR and PMR of 1.50, (1.17-1.89) and the heterogeneity of the data was not significant at the 10% level.

Ma *et al.*, 1998 + A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.

Amongst white firefighters, multiple myeloma had an MOR=1.1 (0.8-1.6), based on 28 deaths. For black firefighters the MOR was 0.8, based upon one death.

3.2.25 Leukaemia

Comparisons of different studies of leukaemia are complicated by the fact that different papers classify this family of cancers in different ways. For example, Aronson *et al* (1994) presents data subdivided into lymphatic leukaemia (ICD 9 : 204) and myeloid leukaemia (ICD 9 : 205) whilst Baris *et al* (2001) presents the leukaemias from ICD 9 : 204 to ICD 9 : 207 as a single group. For the purpose of this review however, all those studies have been grouped together. Twelve papers have been identified which present a risk estimate and confidence interval. One further study, that of Giles *et al*, 1993 is omitted as, although they included leukaemia in their study, they actually observed no cases which yielded a SIR of 0.0 (0.0-3.56). The main findings from the other twelve are shown in Figure 21. From this it can clearly be seen that there is generally an even distribution of risk estimates either side of 1.0. The exception to this is perhaps the study of Aronson *et al* (1994) for lymphatic leukaemia which does show a slightly higher level of risk (although still less than 2.0). None of the risk estimates attained statistical significance.

Of the 12 papers, six presented an estimate of person-years of follow-up (or equivalent). These totalled 1,387,369 person-years, including the two large studies of the mortality and morbidity of Florida firefighters (Ma *et al*. 2005 & 2006) which collectively accounted for in excess of 900,000 person-years.

Three reviews were identified which examined leukaemia in firefighters. A fourth review Guidotti, 1995 clustered the leukaemias with other lymphatic and haemopoetic cancers and is not therefore included here.

Chronologically, the first review is that of Golden *et al* (1995). This identified ten papers, including one older study (Morton *et al*, 1984) not identified in the present review and a second (Feuer and Rosenman, 1986) neither of which are presented here as the papers do not include confidence intervals. However, it should be noted that the risk estimate of Morton *et al* (1984) (SIR = 346) was stated as being statistically significant. Two further results presented by Golden *et al* (1995), which appear to show a considerable excess, are based against a local police cohort rather than the more general population values which are lower. Possibly because of the influence of these latter papers, the authors conclude that the majority of epidemiological studies have found that firefighters are at an increased risk of leukaemia although they do not present any estimate of that risk.

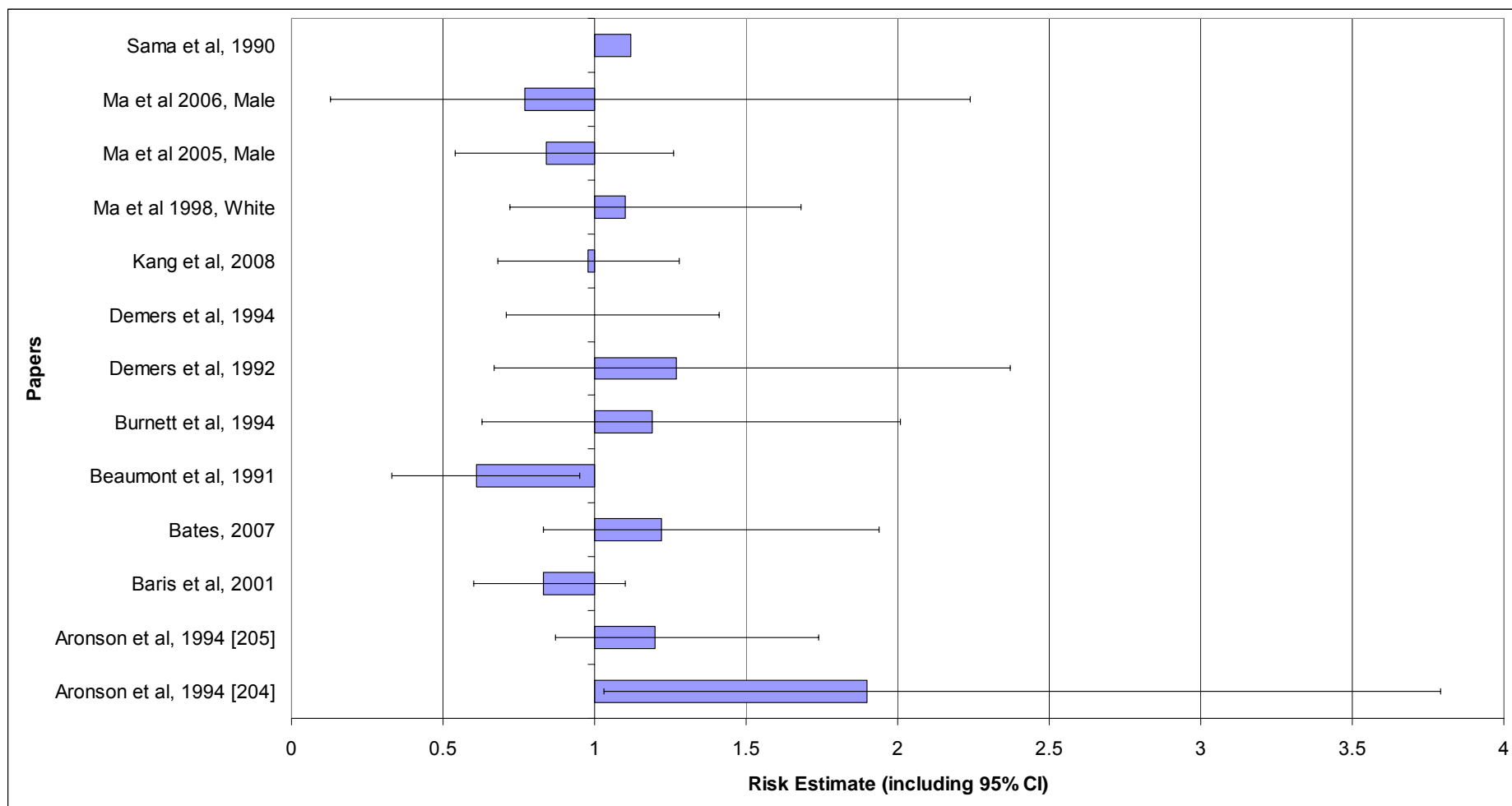
Youakim (2006) utilised nine mortality studies in computing a summed Risk Ratio of 1.08 (0.92-1.23) for all studies and 0.94 (0.71-1.21) for cohort studies. For morbidity / incidence studies the equivalent values were 1.34 (0.82-2.06) and 1.19 (0.57-2.19) respectively. Clearly, although these indicate slight excesses, none of these are statistically significant. Trend studies yielded unclear results, with the series (<10; 10-19; 20-29 years of employment) not revealing any apparent trend but a second series (≥10; ≥20; ≥30 years) showing an excess on mortality for ≥30 years of employment. However, this final figure indicates data from one study, not apparently included in any of the earlier estimates, which might have distorted the outcome.

Finally, LeMasters *et al* (2006) utilised data from eight studies in deriving a summary risk estimate for all studies of 1.14 (0.98-1.31). This review apparently included data from the two earlier studies cited above, as presented by Golden *et al* (1995) as well as the paper by Demers, *et al.*, (1992a). Fortunately, again the findings of this paper were not dissimilar to those of Demers *et al* (1994) although the higher number of incident cases (10 as opposed to 6) would have increased the effective weighting

given to this cohort. However, LeMasters and colleagues excluded the studies by Ma *et al* of mortality (2005) and morbidity (2006) as the range of leukaemias covered was not sufficiently exclusive (and presumably excluded Aronson *et al*, (1994) for the same reason). It also did not include the more recent publications by Bates (2007) and Kang *et al* (2008).

With the omission of these studies taken into account, it is possible that the summed risk estimates calculated by LeMasters *et al* (2006) and Youakim (2006) underestimate the net risk slightly, although the variations in diagnoses included are unhelpful. However, given the variation encompassed by the omitted studies it is unlikely that the overall risk estimate for leukemia and firefighting would be increased by more than a modest amount above these estimates of around 1.1 and would certainly not exceed a value of 2.0.

Table 21 presents the data relating to firefighting and leukemia.



KEY: * indicates risk statistically significantly different from 1.0 ($p=0.05$)

Figure 21: Comparisons of relative risks (with 95% confidence intervals) for Leukaemia, derived from published studies

Table 21. Evidence relating to Fire Fighting and Leukemia

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Aronson <i>et al.</i> , 1994	Historical cohort study of mortality of male firefighters in Toronto. 5,373 were retained after exclusions (e.g. 146 females) from initial cohort of 5,995. FF were sig. less likely to have died from infective or parasitic diseases (SMR 14, 0-78); endocrine/nutritional diseases (SMR 34, 11-80) mainly attributable to diabetes mellitus (4/5 deaths, SMR 35, 9-88); chronic rheumatic heart disease (SMR 15, 0.4-85); ill-defined symptoms (SMR 71, 55-90) or external causes (SMR 71, 55-90). They were more likely to die from cancer of the brain (SMR 201, 110-337); other malignant neoplasms (SMR 238, 145-367) or aortic aneurysms (SMR 226, 136-354). There were signs of a diminishing healthy worker effect with those with <20 years exposure less likely to die (SMR 81, 67-97) although this effect reduced and was no longer sig for longer periods of exposure. Brain cancer was most noticeable in those with <20 years (SMR 283, 104-616) with the effect not sig in longer periods. Other malignant neoplasms (SMR 305, 171-504); aortic aneurysms (SMR 231, 132-375); digestive system diseases (SMR 156, 106-222) and gallbladder disease (SMR 391, 127-912) showed the opposite with more deaths amongst the >30 years group. Other cancers (e.g testicular, SMR 326, 67-953 in the <20 years group) showed non-sig elevations.	++	<p>There were 4 deaths attributed to lymphatic leukemia (ICD 9, 204) in the cohort, yielding a non-significant SMR of 190 (52-488) and 4 deaths attributed to myeloid leukemia (ICD 9, 205), yielding a non-significant SMR of 120 (33-309). Further analysis included lymphatic leukemia.</p> <p>Analysis by years since first exposure showed all the deaths to be clustered in the sub-cohort with the longest period since first exposure (≥ 30 years): <20 years: SMR=0 (0-1025); 20-29 years: SMR=0 (0-997); ≥ 30 years: SMR=292 (80-748). An analysis by years of employment showed the same trend: <15 years: SMR=0 (0-1054); 15-29 years: SMR=0 (0-625); ≥ 30 years: SMR=351 (96-898). Finally, an analysis of deaths by age showed all the deaths in the older of the two sub-cohorts: <60 years: SMR=0 (0-401); ≥ 60 years SMR=336 (92-860).</p>

- Baris *et al.*, 2001 Mortality from cancer and other causes amongst FF in Philadelphia compared to the US white male pop. Study used number of runs and type of work (e.g. engine company & ladder company) as measures of exposure as well as years as firefighter. Also studied exposure specifically diesel exhaust reflecting concerns over switch from petrol to diesel appliances. SMRs for all causes and all cancers were close to 1 although that for all cancers (SMR=1.1; CI 1.0-1.20) could be considered sig. Sig elevated SMRs for colon cancer (SMR=1.51; CI 1.18-1.93) and IHD (SMR=1.09; CI 1.02-1.16). Elevated SMRs but not sig for many other cancers including: buccal/pharynx; bladder; lung; skin; & kidney. Testicular cancer did not feature in the study. Some risks appeared to be associated with years of service but the pattern was not clear. Type of work was associated with several increases. Those from engine stations had increased risks of buccal/pharynx (SMR=2.0; CI 1.11-2.63); colon cancer (SMR=1.94; CI 1.38-2.73); multiple myeloma (SMR=2.54; CI 1.15-5.67); benign neoplasms (SMR=2.95; CI 1.41-6.19); & IHD (SMR=1.14 CI 1.03-1.27). Several others were elevated but ns. Ladder company FF had sig elevated risks of leukaemia (SMR=2.75 CI 1.03-7.33); circulatory diseases (SMR=1.27; CI 1.05-1.52); & IHD (SMR=1.33; CI 1.06-1.65). Several others were elevated but ns. No pattern to analyses by year of hire. Subgroup with data on number of runs did not show any particular pattern differing from main analyses. Analysis by diesel exposure did not show any sig elevations. ++
- Bates 2007 Records of all male cancers registered in California during 1988–2003 were obtained. Of the 804,000 eligible records, 3,659 had firefighting as their occupation. This represents the occupation for which they have been employed the longest, as reported by the individual. Where there was any indication of an administrative, rather than an operational role, the individual was excluded although it is not clear how reliably this would have been recorded. Fire-fighting was significantly associated with testicular cancer (odds ratio=1.54, 1.18–2.02), melanoma (1.50, 1.33–1.70), brain cancer (1.35, 1.06–1.72), oesophageal cancer (1.48, 1.14–1.91), and prostate cancer (1.22, 1.12–1.33). +

15 deaths attributed to leukemia (ICD 9, 204-207) yielded a non-significant SMR of 0.83 (0.50-1.37). In the analysis of duration of employment as a surrogate for exposure there was no linear trend across the three categories: (≤ 9 years, SMR=0.94 (0.39-2.25); 10-19 years, SMR=1.14., (0.54-2.38); ≥ 20 years, SMR=0.45; 0.15-1.40). As an alternative measure of exposure, those who were in ladder companies were significantly more likely to die from leukemia (engine company: SMR=0.28, (0.07-1.12); ladder company: SMR=2.75 (1.03-7.33); both ladder and engine companies: SMR=0.98, (0.16-2.62)). There were suggestions that those recruited earlier were less likely to die from leukemia than those recruited more recently: pre-1935: SMR=0.32 (0.08-1.28); 1935-1944: SMR=1.08, (0.49-2.40); post 1944: SMR=1.10, (0.52-2.31)).

The occupation of fire-fighting narrowly failed to attain a significantly elevated risk associated with leukemia (Odds Ratio=1.22, 0.99–1.49), based on 100 registered cases. Reporting trends were analysed by sub-dividing the results into two sub-cohorts, covering registrations in 1988-1995 and 1996-2003. This yielded risk estimates reasonably close to (and not significantly different from) 1.0: older registrants: OR=1.18 (0.73-1.90); younger registrants: OR=1.06 (0.67-1.69).

Beaumont <i>et al.</i> , 1991	Historical cohort study of cancer and other forms of mortality. 3,066 firefighters, all male, white with at least 3 years service. Analysis for all causes initially and then more detailed breakdown of neoplasms. Sig lower risk of TB (OR 0.26; 0.07-0.68); diabetes mellitus (OR 0.36; 0.14-0.75); diseases of the heart (OR 0.89; 0.81-0.97); diseases of respiratory system (OR 0.63; 0.47-0.83); selected specific respiratory diseases; and 'all causes' (OR 0.90; 0.85-0.95). Sig increased risk of: diseases of the digestive system (OR 1.57; 1.27-1.92); cirrhosis and other liver disease (OR 2.27; 1.73-2.93); and accidental falls. Specific malignant neoplasms showed increased risk of cancers of the digestive organs (OR 1.27; 1.04-1.55); and oesophagus (OR 2.04; 1.05-3.57) and reduced risks of cancers of the genital organs (OR 0.40; CI 0.18-0.77) and the prostate (OR 0.38; 0.16-0.75). Prostate cancer dominated this category (8 out of 9 deaths) with only one death from other genital cancers.	+	The Rate Ratio for leukemia and aleukemia was lower than 1.0, but not significantly (0.61, 0.22-1.33), based on 6 deaths. Exposure-related data did not include this cancer.
Burnett <i>et al.</i> , 1994	Assessment of mortality rates for firefighters using information from 27 USA states between 1984-1990. 5,744 deaths in white male firefighters were reviewed and analysis was based on proportionate mortality ratios comparing deaths from specific causes to all causes. The study identified increased levels of malignant neoplasms (PMR=110; 106-114), rectal cancer (PMR=148; 105-205). skin cancer (PMR=163; 115-223)); kidney cancer (PMR=144; 108-189), lymphatic and haematopoietic cancers (PMR=130 111-151) and multiple myeloma (PMR=148; 102-207).	++	The study identified a small, non-significant increase in risk of leukemia amongst firefighters: PMR=119, (91-153) based upon 61 deaths.

Demers *et al.*, 1992a ++
 A mortality study of male firefighters and police employed between 1944 and 1979 in the North Western USA. Follow-up was made for 4401 firefighters and 1169 deaths occurred with 1162 death certificates. Risk of death due to any cause was less in the firefighters, compared to US population data. However, an excess of brain cancers was identified (SMR=2.09; 95% CI 1.3-3.2), and those under 40 appeared to have an excess risk of brain cancer (SMR=3.75; 95% CI 1.2-8.7) and those with at least 30 years employment the increased risk of lymphatic and haematopoietic cancers was (SMR=2.05; 95% CI 1.1-3.6) and leukaemia (SMR=2.6; 95% CI 1.0-5.4). However the occupational groups were not split and further analysis was based on grouped firefighters and police officers.

Demers *et al.*, 1994 ++
 A study of incidence of cancer in 2477 male firefighters in the USA. Firefighters were employed between 1944 and 1977 for at least one year and resident to Washington State. 94% were followed up until 1989 or death. The number of cancers for all sites was similar to that of all local males. Risk of prostate cancers in comparison to the general population was elevated (SIR=1.4; 1.1-1.7), as was stomach cancer (SIR 1.4; 0.6-2.7) and ocular melanoma (SIR=5.2; 0.6-18.8). The risk of colon cancer (SIR=1.1; 0.7-1.6) was slightly elevated.

Leukemia had an SMR=1.27 (0.71-2.09) based on 15 deaths. Analysis by duration of exposed employment showed signs of a trend, with a significantly elevated risk in the longest-serving cohort: <10years: SMR=1.13 (0.1-4.1); 10-19 years: SMR=1.04 (0.1-3.7); 20-29 years: SMR=0.73 (0.2-1.9); > 30 years: SMR=2.60 (1.0-5.4). A similar analysis by years since first employment showed no trend: <20 years: SIR=1.50, (0.3-4.4); 20-29 years: SIR=0.50, (0.1-2.8); 30+ years: SIR=1.40 (0.7-2.5). The authors analysed the data by age at risk, which showed the oldest sub-cohort to be at an increased, (non-significant) risk: 8-39 years old: SMR=0.82 (0.1-4.6); 40-64 years old: SMR=0.95 (0.3-2.2); >65 years old: SMR=1.67 (0.8-3.2).

Leukemia had an SIR=1.0 (0.4-2.1) based on 6 deaths. An analysis by duration of exposed employment showed no particular pattern: <10 years: 0.0 (0.0-15.7); 10-19 years: 1.9 (0.2-6.8); 20-29 years: 1.1 (0.3-2.8); 30+ years: 0.0 (0.0-5.4). Analysis by years since first employment showed a trend for those recruited most recently to be more at risk although the confidence interval was very wide: <20 years: SIR=1.6 (0.0-8.9); 20-29 years: 1.0 (0.0-5.6); SIR=30+ years: SIR=0.9 (0.2-2.2).

Golden <i>et al</i> 1995	A 'State of the Art Review' of cancer in firefighters summarised some suggestions for potential carcinogenic exposures and some of the research on a series of cancers. Although the methods used for the identification and selection of papers are not given the result appears to be reasonably comprehensive. The authors restrict reporting to summaries of the findings from selected papers and do not attempt any synthesis or express any opinion as to work-relatedness. Cancers summarised are: brain;; haemopoietic and lymphatic (leukaemia, non-Hodgkin's lymphoma; multiple myeloma); genitourinary system (bladder, kidney, prostate, testicular); digestive system (large intestine, liver, pancreatic, stomach, and oesophagus); skin; and lung.	+	The authors identified ten papers, including some based against a local police cohort rather than general population values. Possibly because of the influence of these latter papers, the authors conclude that the majority of epidemiological studies have found that firefighters are at an increased risk of leukaemia, although they do not present any estimate of that risk.
Kang <i>et al.</i> , 2008	A study of cancer incidence in Massachusetts firefighters. Total number of eligible cases was 258,964 white male over 18s from 1987-2003. This was broken down into 2,125 firefighters, 2,763 police officers and 156,890 other occupations. SMORs were calculated for firefighters against all other occupations and there was an increased risk for colon cancer (SMOR 1.36; 95% CI 1.04-1.79) and brain cancer (SMOR 1.9; 95% CI 1.10-3.26). One drawback with this study was the fact that occupational data was obtained from medical records rather than other sources.	++	Leukemia yielded an SMOR=0.98 (0.69-1.39) based on 46 registrations. A slight (non-significant) trend was apparent in the age-stratified data for those in the youngest sub-cohort to be most at risk whilst the middle cohort had a significantly reduced risk of being diagnosed with leukemia: 18-54: SMOR=1.83 (0.66-5.08); 55-74: SMOR=0.43 (0.20-0.96); 75+: SMOR=0.49 (0.17-1.44).
LeMasters <i>et al.</i> , 2006	A meta-analysis of 32 studies of firefighters to determine the cancer risk. A systematic search was carried out to assess the probably, possible or unlikely risk covering 21 cancers. The analysis identified a probable risk of multiple myeloma (SRE=1.53; 95% CI 1.21-1.94), non-Hodgkin lymphoma (SRE=1.581; 95% CI 1.31-1.73), prostate cancer (SRE=1.28; 95% CI 1.15-1.43) and testicular cancer was upgraded to probable (SRE=2.02; 95% CI 1.30-3.13)	++	The authors concluded that a causal association between firefighting and leukemia was possible. The meta-analysis across all forms of study, utilising a total of 8 analyses, yielded a non-significant elevated Summary Risk Estimate of 1.14 (0.98 –1.31) for leukemia. This similar to the meta-SMR and PMR of 1.14, (0.92-1.39) and the heterogeneity of the data was not significant at the 10% level.

Ma et al., 1998	A study of 1883 cancer deaths in the USA including 1817 white firefighters and 66 black firefighters. Mortality odds ratios were calculated for white male firefighters and black firefighters using a database of 24 states from 1984-1993. The results, adjusted for age and time of death, identified that for white firefighters significant risks were found for cancer of all sites combined (MOR=1.1; 95% CI 1.1-1.2), lip (MOR=4.9; 95% CI 1.9-18.3), pancreas (MOR=1.2; 95% CI 1.0-1.5), bronchus and lung (MOR=1.1; 95% CI 1.0-1.2), soft tissue sarcoma (MOR =1.6; 95% CI 1.0-2.7), melanoma (MOR=1.4; 95% CI 1.0-1.9), prostate (MOR=1.2; 95% CI 1.0-1.3), kidney and renal pelvis (MOR=1.3; 95% CI 1.0-1.7), non-Hodgkin's lymphoma (MOR=1.4; 95% CI 1.1-1.7) and Hodgkin's Disease (MOR= 2.4; 95% CI 1.4-4.1). For black firefighters excess risks were identified for brain cancer (MOR=6.9; 95% CI 3.0-16.0), colon cancer (MOR=2.1; 95% CI 1.1-4.0), prostate cancer (MOR=1.9; 95%CI 1.2-3.2) and nasopharynx (MOR=7.6; 95% CI 1.3-46.4). Study was unclear on how comparisons were made between the general population and the race of the group evaluated.	+	Amongst white firefighters, Leukemia had an MOR=1.1 (0.8-1.4), based on 60 deaths. There were no deaths from leukemia amongst the black firefighters.
Ma et al., 2005	A study of Florida firefighters using the general population of Florida as a comparison group. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. Study identified that there were 1411 male and 38 female firefighter deaths between 1972 and 1999 compared with Florida general population. Using standardised mortality ratios, for males there were no excess mortality for cancer overall but there was for male breast cancer (7.41; 1.99-18.96), thyroid cancer (4.82; 1.3-12.34) and bladder cancer (1.95; 1.04-3.33). There were no significant difference for mortality patterns in female firefighters apart from an increased risk atherosclerotic heart disease (3.85; 1.66-7.58)	++	14 deaths from leukemia amongst the male cohort yielded an SMR=0.84 (0.46-1.42). No deaths from this cancer were recorded amongst the female cohort. A subsidiary analysis of eight deaths amongst firefighters with the longest estimated exposure (registered 1972-1976) gave a very similar outcome with SMR=0.74 (0.3-1.45).

Ma <i>et al.</i> , 2006	A study of Florida firefighters using cancer registry data linked to Fire Service databases. In total 36,813 professional firefighters were identified 94.5% male and 5.5% female. The study identified that there were 970 primary cancer incident cases among males and 52 among females between 1981 and 1999. Using standardised incidence ratios, there were no excess risks identified for overall mortality for male firefighters but there was for bladder cancer (1.29; 1.01-1.62); testicular cancer (1.60; 1.2-2.09) and thyroid cancers (1.77; 1.08-2.73). Female firefighters had an increased risk of cancer overall (1.63; 1.22-2.14) with significant site-specific risks for cervical cancer (5.24; 2.93-8.65), Hodgkin's disease (6.25; 1.26-18.3) and thyroid cancer (3.97; 1.45-8.65). Limitations identified in the study included use of the general population of Florida as the comparison group, potential healthy worker effect and no measure of tobacco use.	++	20 registered cases of leukemia amongst the male cohort yielded a SIR=0.77 (0.47-1.19). No cases of this cancer were recorded amongst the female cohort.
Sama <i>et al.</i> , 1990	A study using cancer registry data from Massachusetts in the USA. Samples included 315 male cancer cases between 1982 and 1986; 392 male white police officers and 29,277 State cases. The analysis included SMORS and it was identified that there was an elevated risk of melanoma (SMOR=292; 95% CI 170-503), bladder cancer (SMOR 159; 95% CI 107-414) for firefighters compared to State residents. In comparison with police officers, there was an increase risk in bladder cancer (SMOR=211; 95% CI 107-414) and non-Hodgkin's Lymphoma (SMOR=32; 95% CI 119-898). A number of difficulties with the study were identified by the researchers including the potential for underreporting of cancers.	++	Six registered cases of leukemia gave an SMOR of 112 (48-267). No further analysis was reported for this cancer.

Youakim, 2006

An analysis of 16 studies to identify risk of cancer among firefighters. The study identified an increase in risk of kidney cancer (sumRR 1.25; 95% CI 1.02-1.43) and non-Hodgkin's Lymphoma (sumRR 1.4; 95% CI 1.20-1.60). Further analysis using a sub-cohort of studies was also made based on duration of employment with 30 years or more as a firefighter had an increased risk for colon cancer (sumRR 1.51; 95% CI 1.05-2.11), kidney cancer (sumRR 36.12; 95% CI 1.70-16.00), brain cancer (sumRR 2.53; 95% CI 1.27-7.07) and leukaemia (sumRR 2.87; 95% CI 1.43-5.14). After 40 years employment risks for mortality from colon cancer were (sumRR 4.71; 95% CI 2.03-9.27), kidney cancer (sumRR 36.2; 95% CI 4.03-120.42) and bladder cancer (sumRR 5.7; 95% CI 1.56-14.33).

++

The author utilised nine mortality studies in computing a summed Risk Ratio of 1.08 (0.92-1.23) for all studies and 0.94 (0.71-1.21) for cohort studies. For morbidity / incidence studies the equivalent values were 1.34 (0.82-2.06) and 1.19 (0.57-2.19) respectively. None of these were statistically significant. Trend studies yielded unclear results, with one series (≥ 10 ; ≥ 20 ; ≥ 30 years) showing an excess on mortality for ≥ 30 years of employment. However, this final figure indicates data from one study, not apparently included in any of the earlier estimates, which might have distorted the outcome.

3.3 SUB-GROUPS AT PARTICULAR RISK OF CANCER

Most of the studies reported here examined the risk of cancer in white, male firefighters. In studies not based on USA populations ethnic group was often not described but, based on the main ethnic make-up of the source population, can reasonably be assumed to be Caucasian. In many instances, other groups, such as female firefighters, were deliberately excluded, usually because of lack of numbers. There were a few notable exceptions such as the study by Grimes *et al.* (1991) which looked at firefighters of Caucasian and Hawaiian origins and those by Ma and co-workers (1998, 2005, 2006) which included sizeable cohorts of black (1998) and female (2005, 2006) firefighters. As noted in the overviews of various specific cancers above, these studies did sometimes indicate a difference in risk between such groups and the main cohort of white males. Clearly, the limited numbers of papers which have been able to examine such groups means that there is not enough evidence on which to base any particular recommendations concerning these groups. However, there are growing numbers of firefighters in the UK who are not white males, especially in some of the larger urban brigades. It is therefore recommended that, in the future, any UK-based study pays particular attention to such groups (perhaps with some form of selective sampling to increase their representation in any sample.).

Other exposures might also be important. Tobacco smoking or excessive alcohol consumption are widely identified as risk factors in relation to a number of forms of cancer and many of the studies attempted to accommodate this or, for example, assumed that the smoking and drinking habits of firefighters were no different to the general population. At least one study (Grimes *et al.* 1991) indicated that this might not be a valid assumption. There is limited evidence that interaction effects might make the real picture more complex. For example, Golden *et al.* (1995) cites one paper which apparently identified an increased risk of lung cancer in firefighters who smoked, over a comparison population which also smoked.

Registry-based studies in particular tended to report only the named occupation as firefighter, with no consideration given to any surrogate measure of exposure. As many papers reviewed have indicated, firefighters are potentially exposed to a wide range of possible (or, in some instances, definite) carcinogens. However, the exposures experienced by any individual firefighter will vary widely, not just between brigades but even between individual call-outs. For a substantial number of papers, years of employment or years since first employment serve as surrogate exposure measures and will clearly have some form of relationship to actual exposures. Others have had access to further records providing potentially more meaningful data. Notable examples of these are the papers by Tornling *et al.*, (1994) where city records were used to construct a 'number of fires attended' index, of that by Baris *et al.* (2001) where exposure could be represented by the type of firefighting company which an individual belonged to.

The existence of some form of trend with increasing exposure often provides a valuable insight into the likely work-relatedness of an injury or illness. In most of the papers examined which attempted to account for variations in exposure, years of employment provided the only available surrogate. However, although some isolated papers identified such trends, few were consistently observed across two or more papers using the same criteria. Where such trends were identified they have been outlined in the evidence tables for the different forms of cancer above. One review, Haas *et al.* (2003), focussed particularly on this issue and provides a useful illustration of the problems.

Whilst the presence of a trend can give useful corroboration of the existence of a relationship, it should not be assumed that the failure to identify any such trend necessarily indicates the reverse. Years in job is, at best, an imprecise measure of workplace exposures and, in the case of firefighters, there are many other potential contributory variables. Apart from broad issues such as the type of area served by a particular brigade (e.g. rural or industrial) a firefighter could experience exposure to potential carcinogens in a one-off incident. Indeed, such incidents have sometimes served as a specific focus for investigation of health effects (e.g. Bandaranayake *et al.* (1993). Add in the complexities of changes in typical exposures over time (witness the increasing use, for example, of chipboard or other composite material in furniture compared to solid timber); the wider use of respiratory protective equipment; and improvements in protective clothing and the difficulties in establishing likely exposure in any individual firefighter becomes apparent. As one example, the relatively recent widespread introduction of the use of firehoods amongst UK firefighters has resulted in previously exposed skin of the face and neck now being covered.

A further factor is that such reviews rely heavily on an international literature database which implicitly assumes that a firefighter in one country will experience similar exposures to one in another. Even a passing knowledge of firefighting practices is sufficient to establish that this is not necessarily the case and that potentially significant differences exist in the techniques used, for example, to fight fires.

Finally, not all forms of cancer follow the same time course. Some have a much shorter latency which means that incidences will occur earlier during a firefighter's career, clouding the results from any time-based exposure surrogate.

The review has identified generally modest increases in risk of a number of forms of cancer amongst firefighters collectively. A real possibility exists that variations in exposure to risk amongst the populations studied are masked by the current inadequacies of the methods used to estimate exposure. Unfortunately, given the current state of knowledge, such variations cannot be quantified or their effects assessed.

3.4 FIRE FIGHTING AND CARDIOVASCULAR DISEASES

3.4.1 General Comments

Nine papers were considered within the review in relation to cardiovascular disease. The papers covered Coronary Heart Disease (CHD) including CHD risk factors as well as ill-health retirements and mortality data.

With regard to risk factors in the development of CHD, Kales *et al.*, (2002) examined blood pressure in US firefighters dealing with hazardous waste. The study followed 340 firefighters with baseline resting blood pressures measures made from 1996 to 2000. The analysis calculated hazard ratios and defined normal blood pressure as SBP < 140 mm Hg and DBP < 90 mm Hg. Stage I Hypertension was defined as $140 \leq \text{SBP} < 160$ mm Hg and/or $90 \leq \text{DBP} < 100$ mm Hg with Stage II Hypertension defined as SBP ≥ 160 mm Hg and/or DBP ≥ 100 mm Hg. The results identified that stage II Hypertension was associated with having a BMI above 30 (HR=3; 95% CI 1.12-8.07) and not using medication for blood pressure (HR=4.2; 95% CI 1.96-8.81). The results identified that lifestyle factors were associated with blood pressure but not occupational factors.

Four further studies did not identify an association between CHD and firefighting (Dibbs *et al.*, 1982; Haas *et al.*, 2003; Kales *et al.*, 2009; Glueck *et al.*, 1996). The study by Dibbs *et al.*, (1982), followed up 171 firefighters over a 10 year period and found that the rate ratio calculated was reduced (RR=0.5; 95% CI 0.2-1.4). Furthermore Haas *et al.*, (2003) found no association between fire fighting and coronary artery disease. However, Bates (1987) carried out a cohort study of 596 male firefighters in Canada who were compared with the population of Toronto. On examining deaths from coronary artery disease, identified that there was a significant association between this and fire fighting. SMR were calculated and found to be overall SMR=1.73; 95% CI 1.12-2.66. The study does report that smoking was identified as a potential confounder to the results.

Geibe *et al.*, (2008) examined on-duty coronary events; that is death within 24 hours of the event. Using a sample of 87 fatalities who were compared to 113 survivors, the risk factors identified as being associated with the event included having a diagnosis of CHD (OR=4.09; 95% CI 1.58-10.58), having hypertension (OR=4.15; 95% CI 4.15-9.44) and being a current smoker (OR=3.68; 95% CI 1.61-8.45).

Holder *et al.*, (2006) examined ill health retirement data for cardiovascular disease in the USA. Significant associations were found for age and current hypertension. However, relative risks were also calculated for on-duty events compared to non-emergency incidents and found to be significantly higher during fire suppression (OR=51; 95% CI 12-223) and alarm responses (OR=6.4; 95% CI 2.5-17).

Sardinas *et al.*, (1986) carried out a mortality study of ischemic heart disease in US firefighters compared to police officers. Calculating mortality odds ratios the research found that the proportionate mortality rate for firefighters when compared to police officers and the general population was 1.2 and significant at $p < 0.05$. This study was a mortality study of a large number of different mortality outcomes and a lack of detailed information on employment

At the current time the research is inconclusive with regard to CHD and fire fighting; however lifestyle factors do have an important part to play in its prevention.

Table 22. Evidence for Fire Fighting and Cardiovascular Disease

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Bates, 1987	A cohort study of 596 male firefighters who had worked for 6 years or more. Control group was the population of Toronto. The study examined death from coronary artery disease and identified that there were 21 deaths between the age group 45-54 years. SMRs were calculated and it was identified that overall there was an association between coronary artery disease and firefighting (SMR=1.73 95% CI 1.12-2.66). For the age groups 45-49 was significant at SMR=1.8; 95% CI 1.01-3.19 and for the age group 50-54 the SMR was not significant. Smoking was identified as a potential confounder but a modest degree of association was found.	+	Significant association found for the age group 45-49 years (SMR=1.8; 95% CI 1.01-3.19) and overall (SMR=1.73 95% CI 1.12-2.66).
Dibbs 1982	<i>et al.</i> , Longitudinal study of sub-group of firefighters (171) within larger study group (1475) ie 1646 total. Studied over 10 years. Outcome CHD. Rate ratio of CHD amongst FF was 0.5 (0.2-1.4).	++	Reduction in RR for CHD (0.5) over 10 years
Geibe 2008	<i>et al.</i> , A retrospective analysis of on-duty coronary events in male firefighters in the USA. The study used 87 fatalities (death within 24 hours of the event) compared to 113 survivors. The analysis identified risk factors associated with a coronary death included previous diagnosis of CHD (or peripheral/cerebrovascular disease) OR=4.09; 95% CI 1.58-10.58), current smoking (OR 3.68; 95% CI 1.61-8.45); hypertension (OR 4.15; 95% CI 4.15-9.44). Study recommends early detection and control of hypertension and smoking cessation and restricting duties for those with CHD.	++	The analysis identified risk factors associated with a coronary death included previous diagnosis of CHD (or peripheral/cerebrovascular disease) OR=4.09; 95% CI 1.58-10.58), current smoking (OR 3.68; 95% CI 1.61-8.45); hypertension (OR 4.15; 95% CI 4.15-9.44)

Glueck <i>et al.</i> , 1996	Used data on CHD risk factors and prospectively assessed 806 firefighters for 6.4 years or 5173 person years. CHD factors measured included weight, BP, cigarette use, fasting glucose and lipid profile. The results identified that firefighting as an occupation was not associated with an increase in CHD rates. However predictors associated with CHD included age ($p=0.007$), smoking ($p=0.001$), diastolic BP ($p=0.056$) and a family history at less than 60 years ($p=0.048$)	++	None
Haas <i>et al.</i> , 2003	A systematic review of mortality studies amongst firefighters. Eight were selected for study. Data tables are presented for All Cause mortality (SMRs mainly <1); CHD (SMRs mainly ~ 1); Mortality from All Cancers (SMRs mainly <1); Lung Cancer (SMRs mainly <1 except 1 study); Brain Cancer (SMRs 2-3); & Respiratory Disease (SMRs mainly <1). No CIs are reported from studies but some p values are presented.	+	No association found between coronary artery disease and firefighting.
Holder <i>et al.</i> , 2006	This was a study of ill health retirement for cardiovascular disease in US firefighters. This was a retrospective review of 362 firefighters who received heart presumption pensions and a comparison group of 310 professional firefighters. The study identified that CHD accounted for 77% of all heart retirements, 5% were supraventricular arrhythmias, 3% were cardiomyopathy, 3% cerebrovascular accidents, 1.4% syncope, 1.1 % aortic aneurisms and 1.1% other. Further multivariate analysis identified that being over 45 (OR 7.8; 95% CI 2.0-3.1) and hypertension (OR 4.8; 95% CI 1.3-18) were independent predictors of CHD retirement. Furthermore the estimated relative risk of an on-duty heart retirement compared to nonemergency duty was increased during fire suppression (OR 5.1; 95% CI 1.2-22.3) and alarm response (OR 6.4; 95% CI 2.5-17).	+	Associations found between ill health retirement and a cardiac event for age (OR 7.8; 95% CI 2.0-3.1) and hypertension (OR 4.8; 95% CI 1.3-18) were independent predictors of CHD retirement. Furthermore the estimated relative risk of an on-duty heart retirement compared to nonemergency duty was increased during fire suppression (OR 5.1; 95% CI 1.2-22.3) and alarm response (OR 6.4; 95% CI 2.5-17).

Kales 2002	<i>et al.</i> , A study of blood pressure in firefighters defined as those dealing with hazardous waste in Massachusetts, USA. Participants were 340 firefighters who had baseline measures made in 1996/97 and followed up in 1998, 1999 and 2000. Resting blood pressure measures were made. The analysis of hazards ratios identified that hypertension was associated with having a BMI above 30 (HR=3; 95% CI 1.12-8.07), no medication use for BP (HR=4.2; 95% CI 1.96-8.81). Study highlights the importance of evaluating BP and controlling before being fit for work.	++	Lifestyle factors associated with BP, not occupational
Kales 2009	<i>et al.</i> , This review of risk factors for high blood pressure covers EMS workers. The review identifies that 58% of US career firefighters have prehypertension and 20-23% have hypertension. For volunteer firefighters 58% have prehypertension and 30% have hypertension. Little further evidence given from the paper	+	Study did not measure effect but was more guidance on managing blood pressure.
Sardinas 1986	<i>et al.</i> , A mortality study of ischemic heart disease mortality in firefighters and police officers. The study used data from Connecticut from 1960-78. Mortality odds ratios identified that MOR for police officers was higher than that of firefighters for IHD. Study did not have detailed information on employment.	++	

3.5 FIRE FIGHTING AND HEARING LOSS

3.5.1 General Comments

Four studies were identified with regard to hearing loss in firefighters. Clark *et al.*, (2005) examined 12,609 hearing tests carried over an 11 year period. These data were compared to a matched population from a US standard. The results identified that hearing loss in firefighters was not excessive compared to age-matched controls. The data were also regressed and hearing loss did not decline more than would be expected by ageing.

Ide (2007) examined hearing loss associated with ill-health retirement. The study involved all UK Fire Services but only 25% gave full information and 85% gave information on health and retirement. The data collected included 3366 ill-health retirements and of this 134 (4%) were due to hearing problems. Data were compared with age matched firefighters it as identified that hearing loss was significantly worse when compared to the control group ($p < 0.001$) but there was an overlap between the case and control groups. No further associations were made from this research.

A randomly selected group of 192 male firefighters in the USA had their hearing tested and completed a noise exposure score checklist. The participants' employment time ranged from 6 to 436 months. The results identified that 8 participants had some form of conductive hearing loss. When analysing the audiometry results for the remaining 184 participants, it was identified that there was an accelerated rate of hearing loss compared to non-exposed controls ($p < 0.001$). The authors suggest that this loss is at a rate of one and a half times the rate expected for age-matched controls.

Kales *et al.*, (2001) examined hearing loss in firefighters in the USA involved in hazardous material work. The participants were surveyed in 1996 and 1997 numbered 319 who were age matched with controls. The results identified that 14% of firefighters had high-frequency hearing loss compared with 5% of controls and 12% had broad frequency hearing loss compared with 4% of controls. Relative risks were calculated from this data and the risk of high-frequency loss as a firefighter was $RR=2.9$; 95% CI 1.7-5.1 and broad frequency hearing loss of $RR=2.9$; 95% CI 1.5-5.6. The results indicate that there appears to be an association between fire fighting and hearing loss. However this study involved firefighters working within hazardous waste teams and it is unknown if their noise exposure is generally greater than those involved in general fire fighting.

There is evidence of hearing loss when firefighters are compared to control groups. However, further research is required to examine this further in those involved in general fire fighting specifically in the UK context.

Table 23. Evidence for Fire Fighting and Hearing Loss

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Clark <i>et al.</i> , 2005	A study of hearing levels in firefighters. This included 12,609 tests conducted over an 11 year period including cross-sectional and longitudinal data. Tests were compared against a matched control population from a US standard. Comparisons of the data found that the firefighters did not suffer excessive loss of hearing with age and although hearing did reduce in the 7 year test period, this was less than would be expected due to age alone.	++	None found as a negative study
Ide, 2007	The study aimed to define levels of hearing loss associated with ill health retirement in firefighters and assess the extent hearing loss contributes to accidents. All 59 UK fire brigades contacted but only 25% provided full information, 85% provided medical information and 52% safety information. In total 3366 ill health retirements were used, with 135 (4%) due to audiological problems. A control group of firefighters who had taken ill health retirement was also used. The study identified that hearing loss in the test group was significantly worse than the control group ($p < 0.001$). It was identified that 0.13% of accidents was associated with hearing problems and 7 were due to device failure.	++	None made

Kales 2001	<i>et al.</i> , A study of hearing loss in firefighters in the USA. 340 hazardous materials response team members (336 male) were surveyed in 1996 and 1997. This was compared to two databases using otologically normal populations. Each of the 319 included firefighters were age matched with male control participants. The analysis identified that 46 (14%) of firefighters had high-frequency hearing loss compared with 5% of the databases with a relative risk of 2.9; 95% CI 1.7-5.1. For broad-frequency hearing loss 12% of firefighters compared with 4% of the databases with a relative risk of 2.9; 95% CI 1.5-5.6. Thought this is due to noise exposure.	++	The analysis identified that 46 (14%) of firefighters had high-frequency hearing loss compared with 5% of the databases with a relative risk of 2.9; 95% CI 1.7-5.1. For broad-frequency hearing loss 12% of firefighters compared with 4% of the databases with a relative risk of 2.9; 95% CI 1.5-5.6
Pepe 1985	<i>et al.</i> , A survey of 192 male firefighters in Houston randomly selected with employment ranging from 6 to 436 months. A noise exposure score was developed and a physical examination and hearing test carried out. 8 of the sample were found to have some degree of conductive hearing loss. Of the remaining 184 firefighters, 121 had a significant history of non-occupationally related noise exposure. A non-exposed control group suddenly appears and identifies that there was a significant difference between the study group and the control and that hearing loss increases with time and more than would be expected by age alone.	-	

3.6 FIRE FIGHTING AND HIP OSTEOARTHRITIS

3.6.1 General Comments

Two papers were identified that examined potential associations between fire fighting and hip osteoarthritis. The first was a general review that was assessed as (-) that identified that specific occupational groups including firefighters farmers, construction workers and food processing workers had excess risks of developing hip osteoarthritis (Cooper *et al.*, 1996). However no further data to corroborate this was provided in the paper.

Vingard *et al.*, (1991) (++) which was reported by Cooper *et al.*, (1996) examined a register based cohort of Swedish workers. The sample was 250,217 blue-collar workers including 116,581 males with exposure to high levels physical work and 91,057 with exposure to low levels of physical work; for women 18,434 reported exposure to high physical work with 24,145 reporting low physical work exposures. The analysis identified that the relative risk for firefighters to be hospitalised due to osteoarthritis of the hip was $RR=2.52$; 95% CI 1.38-4.64. This calculation was based on 11 male firefighters out of the total sample. The relative risk of hospitalisation due to osteoarthritis of the knee was $RR=2.93$; 95% CI 1.32-5.46; based on 8 cases among firefighters.

The results suggest that there is an increased risk of hip and knee osteoarthritis among firefighters. However, this is based on one study and further research is required to identify if this is common to all firefighters and specifically in the UK.

Table 24. Evidence for Fire Fighting and Hip Osteoarthritis

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Cooper <i>et al.</i> , 1996	This is a review of occupational activity and risk of hip osteoarthritis. The review suggests that firefighters had an excess risk of developing hip osteoarthritis. Does not give any data to support this.	-	None
Vingard <i>et al.</i> , 1991	A register based cohort study of males and females in Sweden to identify if physical workload had increased the risk of hip and knee osteoarthritis. The sample was 250,217 people from the 1980 census in blue-collar occupations who had reported the same occupation in the previous 2 censuses. Participants were identified from the Swedish Hospital Discharge Register and jobs were coded as to high or low exposure to forces acting on the hip and knee. The analysis identified that firefighters had a relative risk (RR= 2.52; 95% CI 1.38-4.64) of hospitalisation for hip osteoarthritis and RR=2.93; 95% CI 1.32-5.46, for risk of hospitalisation for knee osteoarthritis. A large survey and firefighters were a small group within this.	++	The analysis identified that firefighters had a relative risk (RR= 2.52; 95% CI 1.38-4.64) of hospitalisation for hip osteoarthritis and RR=2.93; 95% CI 1.32-5.46, for risk of hospitalisation for knee osteoarthritis

3.7 FIRE FIGHTING AND ILL HEALTH RETIREMENT

3.7.1 General Comments

One paper was identified that examined ill health retirement among firefighters (Ide, 1998) (+). This was a UK study of 505 male firefighters including 488 ill-health retirements and 17 deaths. The study identified that ill-health retirements were due to musculoskeletal problems (40%), ocular problems (12%), injuries (9.9%), heart disease (9.5%) and mental disorders (8.9%). No measure of effect was made within the study; however the study does give an indication of the health reasons for ill-health retirement in the UK Fire Service.

Table 25. Evidence for Fire Fighting and Ill-health Retirement

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Ide, 1998	A UK study of 505 male firefighters (488 ill health retirements and 17 deaths). None of the deaths was attributable to firefighting. The most reasons for ill health retirement were musculoskeletal (n=202, 40%), ocular (n=61, 12.1%), others (n=58, 11.5%), injuries (n=50, 9.9%), heart disease (n=48, 9.5%) and mental disorders (n=45, 8.9%).	+	No real measure of effect made but gives an indication of ill health retirements and their causes.

3.8 FIRE FIGHTING AND MENTAL HEALTH

3.8.1 General Comments

Four papers were identified in relation to the mental health of firefighters and evidence is summarised in Table 6. Three of the papers did not measure any effect but surveyed firefighters in relation to sources of job stress, symptoms and incident induced stressors (Brown *et al.*, 2002, Lalic *et al.*, 2007, Lalic *et al.*, 2009, Murphy *et al.*, 1994a). Murphy *et al.*'s (1994) study of 1730 firefighters and 253 paramedics used a burnout scale to evaluate cumulative stress reactions. The results identified that paramedics scored significantly higher on the burnout scale ($p < 0.0001$) when compared to firefighters. However, the study was confounded by the fact that 93% of the paramedics surveyed were also firefighters.

Brown *et al.*, (2002) surveyed 750 firefighters in Northern Ireland to identify incident induced stressors. Only 248 usable responses were obtained from a questionnaire survey that included the GHQ-28, the locus of control scale and the coping strategies questionnaire. The analysis identified that higher GHQ scores (indicative of increased psychological distress) were associated with higher external locus of control scores, increased frequency of incident-related negative emotions and higher scores on avoidance coping. The analysis split the sample into those with high incident related stressors and those with lower incident related stressors. Further analysis identified that those with high incident related stressors had increased psychological distress following traumatic incidents. This could be moderated by avoidance coping strategies.

Lalic *et al.*, (2007) surveyed 178 Croatian firefighters using a number of validated scales including the PSS-10 Stress Perception Scale, the COPE questionnaire on coping strategies, the STAI X1 anxiety test and the Beck Depression Inventory. The sample was split into 99 urban firefighters, 44 suburban firefighters and 35 volunteer firefighters. The results suggested that the firefighters did not suffer from negative effects of stress as responses were within the normal range, however scores for depression were significantly lower ($p < 0.001$) compared to population norms. In relation to coping firefighters were found to seek social support sometimes, occasionally ventilate their emotions and sometimes do avoidance behaviour to confront stress. However, this small scale study reports no further data or analysis.

Murphy *et al.* (1994) examined symptoms of cumulative stress and burnout in 1730 professional firefighters and 243 paramedics. A burnout scale from the Symptoms of Stress Inventory was used on both groups. The analysis identified that paramedics scored significantly higher on the burnout scale ($p < 0.0001$) but did have more years of service and more emergency runs ($p < 0.001$). The study was confounded by the fact that 93% of the paramedics were also firefighters.

The final study identified in relation to mental health was a survey of 1672 firefighters in Japan (Saijo *et al.*, 2007). The study used the CES-D and the NIOSH generic job questionnaire. Initial results identified that 22.3% of the sample showed depressive symptoms. Logistic regression analysis identified that depressive symptoms were significantly associated with high variance in workload, high intergroup conflict, high role conflict and low-self esteem. Although a measure of effect was made in the study, the data must be treated cautiously as Japanese firefighters also carry out ambulance and paramedic roles.

At the current time there is limited evidence in relation to mental health in firefighters mainly due to a lack of research within the UK and international context. Thus no measures of effect can be made at this time.

Table 26. Evidence for Fire Fighting and Mental Health

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Brown <i>et al.</i> , 2002	A study of incident induced stressors in firefighters in Northern Ireland. The sample was 750 firefighters with a response rate of 40%, n=300 but usable responses were 248. The study used the GHQ-28, Locus of control Scale, the Coping Strategies Questionnaire and the 28-item measure of incident related stressors. The results identified that higher GHQ scores were associated with increased frequency of incident-related negative emotions ($p<0.001$), external locus of control ($p<0.001$) and higher scores on avoidance coping ($p<0.001$). The analysis split the groups into high incident related stressors and lower incident related stressors and found that low incident related stressors were associated with higher scores on locus of control and lower scores on emotion-focused coping ($p<0.001$). High incident related stressors were associated with higher GHQ scores associated with negative emotion, lower task focused coping and higher avoidance scores ($p<0.001$). Mediation routes identified in the study were that the relationship between locus of control and psychological distress was mediated by avoidance coping ($p<0.05$).	+	Study did not measure effect directly rather examined the routes for mediation in psychological distress, locus of control and avoidance and emotion focused research.
Lalic <i>et al.</i> , 2007	A survey of 178 firefighters in Croatia. The survey used the PSS 10 Cohen Stress Perception Scale, the COPE questionnaire, the STAI X1 and STAI X2 anxiety trait tests and the Beck Depression Inventory. Results identified that firefighters did not suffer the negative effects of stress. All were found to be problem orientated and at times react by avoiding stress.	-	None

Murphy <i>et al.</i> , 1994b	A study of symptoms of cumulative stress reactions and burnouts comparing firefighters and paramedics. The study involved 1730 professional firefighters (rr 87%) and 253 paramedics. However 93% of the paramedics were also firefighters. A burnout scale of 13 items was used selected from the Symptoms of Stress Inventory. Paramedics reported more years of service, more emergency runs ($p<0.001$). Paramedics scored significantly higher on the burnout scale ($P<0.0001$). Study confounded by the fact that 93% of paramedics were also firefighters	-	None
Saijo <i>et al.</i> , 2007	A survey of 1672 firefighters in Japan to identify sources of job stress and depression. Used the CES-D and the Japanese version of the NIOSH generic job questionnaire. Results identified that 373 (22.3%) of the sample showed depressive symptoms. From this sub-group, logistic regression analysis was carried out. This identified that depressive symptoms were associated with high variance in workload (OR 2.05; 95% CI 1.29-3.25). high intergroup conflict (OR 1.91; 95% CI 1.26-2.88), high role conflict (OR 1.87; 95% CI 1.24-2.80) and low self-esteem (OR 5.78; 95% CI 3.93-8.50). One potential difficulty with this study is that firefighters in Japan are also involved in ambulance work.	+	Depressive symptoms were associated with high variance in workload (OR 2.05; 95% CI 1.29-3.25). high intergroup conflict (OR 1.91; 95% CI 1.26-2.88), high role conflict (OR 1.87; 95% CI 1.24-2.80) and low self-esteem (OR 5.78; 95% CI 3.93-8.50). One potential difficulty with this study is that firefighters in Japan are also involved in ambulance work

3.9 FIRE FIGHTING AND RESPIRATORY ILLNESS

3.9.1 General Comments

Nine papers were identified that examined respiratory health in firefighters. One was based on validated questionnaire surveys (Mustajbegovic *et al.*, 2001, Ribeiro *et al.*, 2009); seven used lung function tests (Betchley *et al.*, 1997, Burgess *et al.*, 2004, Miedinger *et al.*, 2007a, Musk *et al.*, 1982, Mustajbegovic *et al.*, 2001, Serra *et al.*, 1996, Sparrow *et al.*, 1982) and one was a mortality study (Rosenstock *et al.*, 1990).

Ribeiro *et al.*, (2009) carried out a questionnaire survey of asthma symptoms comparing firefighters and police officers in Brazil. Using a validated questionnaire, the European Community Respiratory Health Survey, 1,235 firefighters and 1,839 police officers were surveyed with a response rate of 56% of the original sample (N=2,200). The study identified that 30.9% of firefighters reported wheezing, 44.5% reported rhinitis, 17.4% reported waking with chest tightness and 14.7% reported wheezing without a cold. Further analysis was carried out and odds ratios were calculated and working as a firefighter was significantly associated with wheezing (OR=2.20; 95% CI 1.67-2.91), wheezing with breathlessness (OR=1.81; 95% CI 1.3-2.53), wheezing without a cold (OR=3.69; 95% CI 2.47-5.60), waking with breathlessness (OR=2.82; 95% CI 1.77-4.47), rhinitis (OR=1.35; 95% CI 1.13-1.62) and receiving treatment for asthma (OR=7.89; 95% CI 4.18-15.33).

Lung function testing was used in seven studies using different groups of firefighters. Betchley *et al.*, (1997) evaluated the respiratory health of forest firefighters in the USA. The study included a questionnaire survey on health symptoms and smoking and spirometry measures of firefighter's pre and post the firefighting season and pre and post shift. In total 53 firefighters were measured for seasonal analysis and 76 firefighters were measured for cross-shift analysis. The questionnaire results identified that there were no significant differences in self-reported respiratory symptoms either across the season or across shift; reports of cough and phlegm did increase across shift but not significantly. The lung function testing identified that there were significant decreases in FEV₁ (P<0.021) and FEF (p<0.05) across the season. Across the shift, there were significant reductions in FVC (p<0.028), FEV₁ (p<0.004) and FEF₂₅₋₇₅ (p<0.003). The study was cross-sectional over one fire fighting season and the authors suggest that further research is required.

Miedinger *et al.*, (2007) carried out a survey of respiratory symptoms in firefighters in Switzerland. The study included 101 male firefighters and respiratory symptoms, atopy, lung function tests and response to methacholine were measured. A control group for comparison was also used of 735 local male residents. The analysis identified that 51% of firefighters were atopic compared to controls (34%) and firefighters reported a higher level of respiratory symptoms but this was not significantly different. There was a significant association found between a response to methacholine and being a firefighter (OR=2.24; 95% CI 1.12-4.48). This study was found cross-sectional and small. Although an association was found it is not clear when the symptoms began or if they are directly associated with fire fighting.

Mustajbegovic *et al.*, (2001) carried out a questionnaire survey and lung function testing of 128 firefighters in Croatia. The study included the MRC and WHO questions on respiratory symptoms and occupational asthma. The questionnaire was used to assess firefighters and 88 control participants. Lung function testing was carried out on all 128 firefighters and the control was predicted normal values of the Croatian population. The analysis identified that there was a significantly higher reported prevalence of dyspnoea, nasal catarrh, sinusitis and hoarseness when

compared to the control group ($p < 0.001$). For the lung function tests a number of associations were identified with being a firefighter including chronic phlegm (OR=1.973; 95% CI 1.051-6.974), chronic bronchitis (OR=1.998; 95% CI 1.01-4.436), and dyspnoea (OR=1.989; 95% CI 1.035-3.299). In comparing measured lung function results firefighters had significantly lower FVC ($p < 0.05$), FEV₁ ($p < 0.01$), FEF₅₀ ($P < 0.01$) and FEF₇₅ ($p < 0.01$) when compared to Croatian norms. This research was cross-sectional in design and small. However, no measurement of effect was made from this work.

Serra *et al.*, (1996) examined lung function in Sardinian firefighters. The study involved 92 firefighters with a control group of 51 police officers. Participants completed a questionnaire on occupational factors, hobbies and smoking habits. Lung function tests were carried out using the procedures of the ECCS. In comparing the two groups firefighters had a significantly lower FEV₁ ($p < 0.05$), FEV₁/FVC ($p < 0.001$), FEF₇₅ ($p < 0.05$), FEF₅₀ ($P < 0.01$), FEF₂₅ ($P < 0.001$) and RV ($p < 0.01$). Although there were significant reductions in lung function tests compared to police officers, no significant correlations were found between length of service, number of fires attended and respiratory measures. This was a small cross-sectional sample of firefighters and no measures of association were made.

Three longitudinal studies of respiratory function in firefighters were included in the review. Musk *et al.*, (1982) followed 951 US firefighters between 1970 and 1976. Annual measures were made during the study using both a questionnaire and lung function tests. The focus of the analysis was on FEV₁ and FVC. The results indicated that there was no correlation with either firefighting activity or other activities and the decline was similar to that expected with age-related change. No further measurement of effect was made in the study.

Burgess *et al.*, (2004) carried out a longitudinal study of 2,492 firefighters (current and present) over a period of 10 years. The analysis was made on 1,204 firefighters who had at least 6 lung function tests. The results for FEV₁ identified that both age and having an initially greater FEV₁ were associated with a significant decline in this parameter ($P < 0.001$).

Sparrow *et al.*, (1982) carried out lung function testing in 168 (79.2% retention at 5 years) firefighters compared to 1,474 controls (78.2% retention at 5 years). The participants were taking part in a research study on ageing. Lung function measures identified that FCV in firefighters was significantly lower than controls ($p < 0.007$) and FEV₁ approached significance ($P = 0.054$). No relationships were found when examining years of employment or symptoms or disease. No further measures of effect were made in this study.

One mortality study by Rosenstock *et al.*, (1990) examined rates for 4392 firefighters compared to 2074 police officers. Standardised mortality ratios were calculated in this research. When comparing firefighters with the population, the SMR for all causes of death was lower than the general population. However, for non-malignant respiratory diseases there was an increased risk calculated (SMR=159; 95% CI 109-387) when compared to police officers. The authors suggest the results should be treated cautiously as the results may be due to the police officers having lower death rates. More research would confirm these results.

The evidence for fire fighting having a negative impact on respiratory health is inconclusive as the majority of the research is based on small cross-sectional studies. However, these studies indicate a potential effect but it is hoped that current practice in the use of PPE will ameliorate this.

Table 27. Evidence for Fire Fighting and Respiratory Illness

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Betchley <i>et al.</i> , 1997	A study of respiratory health in forest firefighters in the USA. Measures were made on those exposed to high concentrations of smoke during their shift. Participants were split into different groups. 96, took part in pre-season testing, 76 too part in cross-shift testing and 53 took part in post-season testing. The results identified that there were indicant decreases in FVC, FEV ₁ and FEF of 0.065l (1%), 0.150 l (3%) and 0.496 l/sec (6%). For cross season testing, there were no significant reductions in FVC but FEV ₁ and FEF were reduced significantly	+	Short term study with no long term effects measured.
Burgess <i>et al.</i> , 2004	A longitudinal study of US firefighters measuring FEV ₁ over 10 years. The study followed 2492 past and current firefighters and this was broken down into firefighters who had 6 or more annual pulmonary function tests (n=1204) and firefighters with single nucleotide polypeptides (SNPs) and at least 6 pulmonary function tests (n=379). Analysis of the data identified that increased age and greater initial FEV ₁ was associated with a significant decline in FEV ₁ (P<0.001).	++	Analysis of the data identified that increased age and greater initial FEV ₁ was associated with a significant decline in FEV ₁ (P<0.001)

Miedinger <i>et al.</i> , 2007b	A study of 101 firefighters in Basle Switzerland who were compared with 735 male participants resident in Basle. Use of a questionnaire survey of respiratory symptoms and skin-prick tests uses different mixes of potential allergens. Also lung function tests, exhaled carbon monoxide and atopy (through allergy tests) and physician diagnosed asthma. Results identified that 51% of firefighters were atopic compared to 34% of the control group. Firefighters reported more respiratory symptoms compared to controls but this was not significant. Firefighters also reported the following symptoms more frequently during work when compared to controls; including burning eyes (21% versus 3%), running nose (19% versus 2%), itchy throat (26% versus 3%), cough (28% versus 3%) and headaches (25% versus 3%). Odds ratio of a response to methacholine was OR=2.24; 95% CI 1.12-4.48 for firefighters.	+	None
Musk <i>et al.</i> , 1982	Longitudinal study of pulmonary function in firefighters. Looked at functional measures (FEV, FVC) and symptoms (cough) in 951 (54% retention) firefighters. Study found no correlation of any changes with firefighting activity or other parameters and decline was in line with expected for age.	+	No sig effects on respiratory health over time.

Mustajbegovic <i>et al.</i> , 2001	A questionnaire survey using the British Medical Research council questionnaire and WHO questions on occupational asthma. Ventilatory capacity measurements were also made in all 128 firefighters. Predicted norms for controls from the Croatian population were used as comparators. 88 control workers were also used for the questionnaire survey. The results identified that there was a higher reported prevalence of dyspnoea, nasal catarrh, sinusitis, and hoarseness compared to controls ($p < 0.001$). Logistic regression analysis identified that chronic bronchitis was associated with age (OR 1.063; 95% CI 1.003-1.201); chronic phlegm was associated with being a firefighter (OR 1.973; 95% CI 1.051-6.974), as was chronic bronchitis (OR 1.998; 95% CI 1.010-4.436) and dyspnoea (OR 1.989; 95% CI 1.035-3.299). Being a firefighter and smoking was associated with chronic cough (OR 14.748; 95% CI 5.046-55.559), chronic phlegm (Or 13.758; 95% CI 4.050-71.061) and chronic bronchitis (OR 16.283; 95% CI 4.991-75.394).	+	Logistic regression analysis identified that chronic bronchitis was associated with age (OR 1.063; 95% CI 1.003-1.201); chronic phlegm was associated with being a firefighter (OR 1.973; 95% CI 1.051-6.974), as was chronic bronchitis (OR 1.998; 95% CI 1.010-4.436) and dyspnoea (OR 1.989; 95% CI 1.035-3.299). Being a firefighter and smoking was associated with chronic cough (OR 14.748; 95% CI 5.046-55.559), chronic phlegm (Or 13.758; 95% CI 4.050-71.061) and chronic bronchitis (OR 16.283; 95% CI 4.991-75.394).
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Ribeiro 2009	<i>et al.</i> , A validated questionnaire survey of asthma symptoms in firefighters and police officers in Brazil. In total 2,200 questionnaires distributed to firefighters with 1,480 (response rate of 67%) returned. Incomplete questionnaires numbered 245 leading to an analysis of 1,235 (56%) of the sample. Study identified that 30.9% reported wheezing, 44.5% reported rhinitis, 7% reported treatment for asthmas and 14% reported waking with breathlessness. Multiple logistic regression identified that wheezing was associated with work as a firefighter (OR 2.2; 95% CI 1.67-2.91), as were wheezing with breathlessness (OR 1.81; 95% CI 1.3-2.53), wheezing without a cold (OR 3.69; 95% CI 2.47-5.60), waking with breathlessness (OR 2.82; 95% CI 1.77-4.47), rhinitis (OR 1.35; 95% CI 1.13-1.62) and receiving treatment for asthma (OR 7.89; 95% CI 4.18-15.33). However, these were questionnaire responses with no physical measures taken.	+	Multiple logistic regression identified that wheezing was associated with work as a firefighter (OR 2.2; 95% CI 1.67-2.91), as were wheezing with breathlessness (OR 1.81; 95% CI 1.3-2.53), wheezing without a cold (OR 3.69; 95% CI 2.47-5.60), waking with breathlessness (OR 2.82; 95% CI 1.77-4.47), rhinitis (OR 1.35; 95% CI 1.13-1.62) and receiving treatment for asthma (OR 7.89; 95% CI 4.18-15.33)
Rosenstock <i>al.</i> , 1990	<i>et</i> This study examined 4392 firefighters and 2074 police officers and compared this data with the USA population. Standardised mortality ratios were calculated. The results identified SMR for firefighters was significantly lower than the population as a whole. There was no significant difference in risk of non-malignant circulatory diseases. Firefighters compared to police officers had an increased risk (non-significant) non-malignant circulatory diseases but did have an increased risk (SMR=159; 95% CI 109-387) of non-malignant respiratory diseases. This was explained by firefighters dying after the age of 40.	++	There was no significant difference in risk of non-malignant circulatory diseases. Firefighters compared to police officers had an increased risk (non-significant) non-malignant circulatory diseases but did have an increased risk (SMR=159; 95% CI 109-387) of non-malignant respiratory diseases.

Serra <i>et al.</i> , 1996	A case control study in Sardinia involving 95 firefighters (meanly dealing with forest fires) and 51 police officers. Data was collected via questionnaire and Forced Vital Capacity measures. The results identified that firefighters had significantly lower FEV1 ($p<0.05$), FEV ₁ /FVC ($p<0.001$), FEF ₇₅ ($P<0.05$), FEF ₅₀ ($P,0.01$), FEF ₂₅ ($p<0.001$) and RV ($p<0.01$). No significant correlation was found between years of service, number of fires extinguished and respiratory data.	+	None
Sparrow <i>et al.</i> , 1982	Longitudinal study of pulmonary function in firefighters. Looked at functional measures (FEV, FVC) and symptoms in 168 (79.2% retention) firefighters and 1,474 non-firefighters (78.2%). Data was adjusted to allow for the initially higher levels of pulmonary function amongst the firefighter group. The study found a decrease in pulmonary function (FVC & FEV ₁) in firefighters. The decline in FVC was sig ($p=0.007$), that for FEV ₁ approached sig ($p=0.054$). However, no relationship with years of employment could be shown. There were no sig differences in symptoms or disease.	+	Study found a decrease in pulmonary function (FVC & FEV ₁) in firefighters. The decline in FVC was sig ($p=0.007$), that for FEV ₁ approached sig ($p=0.054$). However, no relationship with years of employment could be shown. There were no sig differences in symptoms or disease.

3.10 FIRE FIGHTING AND SARCOIDOSIS

3.10.1 General Comments

Two papers were included in the review in relation to sarcoidosis in firefighters. The first was a study of a cluster of sarcoidosis in three US firefighters (Kern *et al.*, 1993). The cluster was identified in a group of firefighters who had trained together. A larger investigation of the group who had trained together including 595 firefighters was carried out. The control group for the research were 686 police officers. The study involved a case-finding questionnaire followed by a laboratory study on 46 classmates, 53 control firefighters and 50 police officers. The laboratory investigations included chest radiography, T-lymphocyte activation tests and chlamydial serology tests. One further case of sarcoidosis was identified in the firefighter group. The analysis identified that firefighters was significantly associated with neopterin elevation (OR=5.8; 95% CI 1.3-26.9). However it was unclear from this finding whether there is an increased risk of T-lymphocyte activation and whether this in turn is an increased risk of lymphocytic alveolitis – as measured by neopterin levels still requires further investigation. Further research is required to confirm this.

The second paper reported on a health surveillance programme between 1985 and 1998 for sarcoidosis in New York firefighters. During the study period, 21 new cases and 4 previous cases were identified by biopsy. In comparing this data with other groups including emergency health care workers in New York, the incidence was greater in firefighters with an average of 12.9/100,000 compared to 0 in the control group. The point prevalence of both groups was measured in 1998 and it was found firefighters had a point prevalence of 222/100,000 with emergency health care workers at 35/100,000. No measures of effect were made in this study and further research is required to identify if there is a significant association.

At the current time no association between fire fighting and sarcoidosis can be made.

Table 28. Evidence for Fire Fighting and Sarcoidosis

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Kern <i>et al.</i> , 1993	A study of a cluster of sarcoidosis in firefighters. Three identified who had trained together in 1979. Study surveyed 595 firefighters and 686 police officers. This was followed by a laboratory study including chest radiography including T lymphocyte activation and chlamydial serology tests. Laboratory tests were carried out on 46 classmates, 53 firefighter controls and 50 police officers. Serum neopterin was elevated in the firefighters and firefighting was associated with this (OR 5.8; 95% CI 1.3-26.9). Study states more research required as to whether this reflects an increase risk of lymphocytic alveolitis and whether firefighters are more at risk of developing sarcoidosis.	+	Firefighting associated with an increased level of neopterin (OR 5.8; 95% CI 1.3-26.9).
Prezant <i>et al.</i> , 1999	The study reports on a health surveillance programme for sarcoidosis in New York firefighters. Programme was initiated in 1985 and ran until 1998. Firefighters were reviewed and any with signs or symptoms of pulmonary disease were referred on. All x-rays taken as part of health surveillance were reviewed. Control groups included EMS HCWs in New York. 25 firefighters were identified with biopsy-proven sarcoidosis. Annual incidence ranged from 0 to 43.6 /100,000 with an average of 12.9/100,000. The results indicated an incidence greater than controls whose annual incidence was 0 in 1998 and point prevalence was 35/100,000.	++	

3.11 FIRE FIGHTING AND WORK RELATED INJURIES

3.11.1 General Comments

Three studies were included in this section in relation to workplace injuries. No specific findings were made as a result of their inclusion. Lee *et al* (2004) calculated risks for hospitalisation of firefighters in the USA. Included in the analysis were a sample of 923 firefighters in a total group of 235,897 males between 18 to 64 years. The results identified that there was a significant association in being a firefighter aged 30-39 years and being hospitalised (OR=1.93; 95% CI 1.21-3.09) and significantly lower for firefighters aged 50-64 years (OR=0.22; 95% CI 1.21-3.09). This may be reflective of either changes in risk perception or changes in exposure to hazards. However no further analysis was made of this data.

Zeitz *et al.*, (2000) examined injuries from exposure to hazardous substances by responders to emergency events including firefighters, emergency medical services and health care workers. A total of 196 firefighters were included in the study. The paper identified that 30.8% of firefighters were involved in fixed-facility incidents and 16.9% were involved in transport incidents. The paper did not break the results down into different occupational groups and types of injuries.

Finally Szubert *et al.*, (2002) examined work-related injuries in Polish firefighters. The study involved 1503 firefighters who were followed-up for a period of 3 years. Analysis identified that there were 352 injuries involving 301 individuals giving an annual injury ratio of 70.3/100 workers.. Forty per cent of all injuries occurred during physical training. On-duty injuries were a total of 25% of all accidents with those broken down into dislocations, strains and sprains (30.4%), giving an absence ratio of 24.5/100 workers and burns (19.4%) giving an absence ratio of 19.7 days/100 workers. The authors suggest that compulsory physical training needs to be managed better to reduce the risk of injury from this source.

In summary there is limited research available on specific workplace injuries for fire fighting at the current time.

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Table 29. Evidence for Fire Fighting and Work-related Injuries

Author	Key points about the study including outcomes	Study quality assessment	Measure of effect
Lee <i>et al.</i> , 2004	A study of risk of hospitalisation of firefighters using data derived from a US sample of 235,897 employed males (aged 18 to 64) collected annually by the NCHS in the USA. Within this there were 923 firefighters. The analysis identified that the odds ratios of being hospitalised during the 12 months preceding the interview were highest for firefighters in the age group 30-39 (OR=1.93; 95% CI 1.21-3.09).	+	Increased risk of hospitalisation in firefighters aged 30-39 years.
Szubert <i>et al.</i> , 2002	A study of work-related injuries in firefighters in Poland. Fire stations were randomly assigned and data collected over 3 years representing 1503 firefighters and 29 fire stations. The results identified that 40% of all injuries occurred during physical training, responsible for 119.1 days of absence per 100 workers annually. On-duty injuries made up 25% of injuries an 72 days of absence per 100 workers annually, 13.7% of injuries were on-duty activities at the fire station at 37.6 days of absence per 100 worker annually and maintenance and repair work was 10% of all injuries with 28.5 days of absence. Main injuries during physical training were leg injuries including dislocations, sprains and strains. For on-duty injuries these included sprains and strains (57%), burns (11%). Authors suggest a need to manage this better for reduce physical training injuries.	+	None

Zeitz <i>et al.</i> , 2000	A study of injuries from exposure to hazardous substances by responders to emergency events. Covers a number of occupational groups including EMS and HCWs. The data was taken from 14 US state health departments from 1996-1998. It identified that 89 (30.8%) of incidents involved firefighters in fixed-facility incidents and 10 (16.9%) involved transport. There was no breakdown of occupation with type of exposure.	+	None
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Pepe PE, Jerger J, Miller RH, Jerger S. (1985). Accelerated hearing loss in urban emergency medical services firefighters. *Annals of Emergency Medicine*; 14: 438-442.

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Saijo Y, Ueno T, Hashimoto Y. (2007). Job stress and depressive symptoms among Japanese fire fighters. *American Journal of Industrial Medicine*; 50: 470-480.

Sama SR, Martin TR, Davis LK, Kriebel D. (1990). Cancer incidence among Massachusetts firefighters, 1982-1986. *American Journal of Industrial Medicine*; 18: 47-54.

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Serra A, Mocci F, Randaccio FS. (1996). Pulmonary function in Sardinian fire fighters. *American Journal of Industrial Medicine*; 30: 78-82.

Sparrow D, Bosse R, Rosner B, Weiss ST. (1982). The effect of occupational exposure on pulmonary function: a longitudinal evaluation of fire fighters and nonfire fighters. *The American Review of Respiratory Disease*; 125: 319-322.

Stang A, Jockel KH, Baumgardt-Elms C, Ahrens W. (2003). Firefighting and risk of testicular cancer: results from a German population-based case-control study. *American Journal of Industrial Medicine*; 43: 291-294.

Straif K, Baan R, Grosse Y, Secretan B, El Ghissassi F, Bouvard V, Altieri A, Benbrahim-Tallaa L, Coglian V. (2007). Carcinogenicity of shift-work, painting, and fire-fighting. *The Lancet Oncology*; 8: 1065-1066.

Szubert Z, Sobala W. (2002). Work-related injuries among firefighters: sites and circumstances of their occurrence. *International Journal of Occupational Medicine and Environmental Health*; 15: 49-55.

Tornling G, Gustavsson P, Hogstedt C. (1994). Mortality and cancer incidence in Stockholm fire fighters. *American Journal of Industrial Medicine*; 25: 219-228.

Vena JE, Fiedler RC. (1987). Mortality of a municipal-worker cohort: IV. Fire fighters. *American Journal of Industrial Medicine*; 11: 671-684.

Vingard E, Alfredsson L, Goldie I, Hogstedt C. (1991). Occupation and osteoarthritis of the hip and knee: a register-based cohort study. *International Journal of Epidemiology*; 20: 1025.

Youakim S. (2006). Risk of cancer among firefighters: a quantitative review of selected malignancies. *Archives of Environmental & Occupational Health*; 61: 223-231.

Zeitz P, Berkowitz Z, Orr MF, Haugh GS, Kaye WE. (2000). Frequency and type of injuries in responders of hazardous substances emergency events, 1996 to 1998. *Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine*; 42: 1115-1120.

APPENDIX A SEARCH STRATEGY

Search Strategy IIAC Fire-fighters

Population

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

Outcomes

Disease
Illness
Prevalence
Incidence
Severity
Duration
Disease/illness complications
Ill-health
Occupational disease
Occupational health
Health status
Health problems
Chronic illness/disease
Acute illness/disease
Injury
Cardiovascular
Respiratory disease
Occupational exposure
Cancer
Sarcoidosis
Skin disease/dermatitis
Mental health/wellbeing

Specific work factors/workplace factors associated with specific health problems
Impact of the work factor on the health problem (relative risk, odds ratio)
Work factors
Work-related factors
Risk factors
Occupational exposure (chemical, dust, smoke, heat, clothing, respiratory, noise)
Work-related illness

Study Designs

Systematic reviews
RCTs
Case control studies
Cross-sectional studies
Observational studies

Inclusion Criteria

Studies containing usable data
In English

Exclusion Criteria

Although initial searches adopted date limitations these were subsequently removed

Studies containing no data
Non-English language

Search Tools**Databases**

Medline
PsychInfo
Science Citation Indexes

Websites

NIOSH
European Agency for Safety and Health
HSE

Organisations

Home Office Fire Research Group
FBU

APPENDIX B NOTES FOR REVIEWING AND DATA EXTRACTION

In using this checklist it is aimed to answer questions of the type “what are the effects of this exposure?”. It has been designed for use with a variety of studies from Meta-analysis to expert opinion or consensus. The following notes aim to give guidance on completion of the spreadsheet.

Section 1 (Yellow)

This section identifies the study by ID number (Ref Works Number) and the initials of the reviewer. The first question relates to whether the study is included or rejected from the review. If the study is rejected, reasons should be documented in column E.

Study type is the next section to be addressed and should be described as one of the following, the numbers relate to column G

Meta-analysis	1
Systematic review of RCTs	1
Randomised Controlled Trial (RCT)	1
Systematic Review of non-RCTs	2
Quasi-experimental (experimental study without randomisation)	2
Cohort Study	3a
Case control Study	3b
Observational studies without control group	4
Consensus or expert opinion	5

The reviewer is then asked to consider a series of questions in relation to the aspects of the study design. The spreadsheet is set up to allow the following responses to the questions.

- Well covered
- Adequately addressed
- Poorly addressed
- Not addressed (i.e. not mentioned, or indicates that this aspect of study design was ignored)
- Not reported (i.e. mentioned, but insufficient detail to allow assessment to be made)
- Not applicable.

The study addresses a clearly focused question

Unless a clear and well defined question is specified, it will be difficult to assess how well the study has met its objectives or how relevant it is to the question you are trying to answer on the basis of its conclusions

If there is a control group, it is taken from a relevant population

Study participants may be selected from the target population (all individuals to which the results of the study could be applied), the source population (a defined subset of the target population from which participants are selected), or from a pool of eligible subjects (a clearly defined and counted group selected from the source population). **If the study does not include clear definitions of the source population it should be rejected.**

Diagnostic method or outcome measures recognised

The methods used for diagnosis of medical effect or measures of outcome should be validated and recognised measures.

Study outcomes clearly defined

Once enrolled in the study, participants should be followed until specified end points or outcomes are reached. In a study of the effect of exercise on the death rates from heart disease in middle aged men, for example, participants might be followed up until death, or until reaching a predefined age.

The measure of assessment of exposure is reliable.

A well conducted study should indicate how the degree of exposure or presence of prognostic factors or markers was assessed. Whatever measures are used must be sufficient to establish clearly that participants have or have not received the exposure under investigation and the extent of such exposure, or that they do or do not possess a particular prognostic marker or factor. Clearly described, reliable measures should increase the confidence in the quality of the study.

Potential confounders are taken into account in the design and the analysis

Confounding is the distortion of a link between exposure and outcome by another factor that is associated with both exposure and outcome. The possible presence of confounding factors is one of the principal reasons why observational studies are not more highly rated as a source of evidence. The report of the study should indicate which potential confounders have been considered, and how they have been assessed or allowed for in the analysis. Clinical judgement should be applied to consider whether all likely confounders have been considered. If the measures used to address confounding are considered inadequate, the study should be downgraded or rejected, depending on how serious the risk of confounding is considered to be.

Confidence intervals are provided

Confidence limits are the preferred method for indicating the precision of statistical results, and can be used to differentiate between an inconclusive study and a study that shows no effect. Studies that report a single value with no assessment of precision should be treated with extreme caution.

Section 2 (Purple)

Asks you to summarise key findings about the study that will be used when you come to formulate recommendations at a later stage of the process.

Section 3 (Blue) relates to the overall assessment of the paper. It starts by rating the methodological quality of the study, based on your responses in Section 1 and using the following coding system:

++	All or most of the criteria have been fulfilled. Where they have not been fulfilled the conclusions of the study or review are thought very unlikely to alter.
+	Some of the criteria have been fulfilled. Those criteria that have not been fulfilled or not adequately described are thought unlikely to alter the conclusions.
–	Few or no criteria fulfilled. The conclusions of the study are thought likely or very likely to alter.

The code allocated here, coupled with the study type, will decide the **level of evidence** that this study provides.

The final question asks for a statement on the measure of effect identified within the paper. This will be used for the second stage of the review to identify if there is a doubling of risk.

If the reviewers wish to add any final comments to the spreadsheet this should be placed in the final column.

APPENDIX C EXCLUDED PAPERS

Authors	Reason for Rejection
Boal WL, Hales T, Ross CS. (2005). Blood-borne pathogens among firefighters and emergency medical technicians. <i>Prehospital Emergency Care: Official Journal of the National Association of EMS Physicians and the National Association of State EMS Directors</i> ; 9: 236-247.	Review of potential exposure to blood borne pathogens but there are no records of firefighter exposures
Bos J, Mol E, Visser B, Frings-Dresen M. (2004). Risk of health complaints and disabilities among Dutch firefighters. <i>International Archives of Occupational and Environmental Health</i> ; 77: 373-382.	A questionnaire survey based comparison study between firefighters and office workers. All based on self-report and no diagnosis
Calvert GM, Barnett M, Mehler LN, Becker A, Das R, Beckman J, Male D, Sievert J, Thomsen C, Morrissey B. (2006). Acute pesticide-related illness among emergency responders, 1993-2002. <i>American Journal of Industrial Medicine</i> ; 49: 383-393.	Measure of acute exposure to pesticides, no longitudinal data.
Fleming JL, England TL, Wernick HB, Reinhart S, Dominguez JA, Kelley PL, Gorter FD, Papst V, LaDuke A. (2006). Case-Control study of Firefighters with documented positive tuberculin skin test results using Quantiferon-TB testing in comparison with Firefighters with negative tuberculin skin test results. <i>Journal of Occupational Medicine and Toxicology (London, England)</i> ; 1: 28.	Evaluation of a testing tool for TB as previous method picks up too many false positives.
Glueck CJ, Kelley W, Gupta A, Fontaine RN, Wang P, Gartside PS. (1997). Prospective 10-year evaluation of hypobetalipoproteinemia in a cohort of 772 firefighters and cross-sectional evaluation of hypocholesterolemia in 1,479 men in the National Health and Nutrition Examination Survey I. <i>Metabolism: Clinical and Experimental</i> ; 46: 625-633.	A study of hypobetalipoproteinemia but not exclusively firefighters. Outcomes were general population and race based rather than occupation based.
Greven F, Kerstjens HA, Duijm F, Eppinga P, de Meer G, Heederik D. (2009). Respiratory effects in the aftermath of a major fire in a chemical waste depot. <i>Scandinavian Journal of Work, Environment & Health</i> ; 35: 368-375.	One-off incident in chemical waste depot, evaluated emergency first responders and residents
Guidotti TL. (2007). Evaluating causality for occupational cancers: the example of firefighters. <i>Occupational Medicine (Oxford, England)</i> ; 57: 466-471.	This paper describes the issues of evaluating causality for occupational cancers and is an example paper. The literature included within it is already covered by the review. It does not add to the body of research.

Kelly KJ, Connelly E, Reinhold GA, Byrne M, Prezant DJ. (2002). Assessment of health effects in New York City firefighters after exposure to polychlorinated biphenyls (PCBs) and polychlorinated dibenzofurans (PCDFs): the Staten Island Transformer Fire Health Surveillance Project. <i>Archives of Environmental Health</i> ; 57: 282-293.	Acute exposure to PCBs, no health effects measured and focus was on how good the uniforms were.
Mapp CE, Boschetto P, Maestrelli P, Fabbri LM. (2005). Occupational asthma. <i>American Journal of Respiratory and Critical Care Medicine</i> ; 172: 280.	Review article on Occupational Asthma mentions World Trade Center firefighters but does not go into other detail on firefighters and OA.
Melius JM. (1995). Cardiovascular disease among firefighters. <i>Occupational Medicine (Philadelphia, Pa.)</i> ; 10: 821-827.	Inadequate selection process
Morren M, Dirkzwager AJ, Kessels FJ, Yzermans CJ. (2007). The influence of a disaster on the health of rescue workers: a longitudinal study. <i>CMAJ: Canadian Medical Association Journal = Journal De l'Association Medicale Canadienne</i> ; 176: 1279-1283.	Study of one-off disaster.
Nagaya T, Yoshida H, Takahashi H, Kawai M. (2006). Policemen and firefighters have increased risk for type-2 diabetes mellitus probably due to their large body mass index: a follow-up study in Japanese men. <i>American Journal of Industrial Medicine</i> ; 49: 30-35.	This study on increased risk of Type-2 diabetes groups together policemen and firefighters. No way to break this down in the analysis.
Ray MR, Basu C, Roychoudhury S, Banik S, Lahiri T. (2006). Plasma catecholamine levels and neurobehavioral problems in Indian firefighters. <i>Journal of Occupational Health</i> ; 48: 210-215.	A small study of endocrine measures and neuroendocrine symptoms. Does not further levels of knowledge.
Reich NE. (1953). Firefighting and heart disease. <i>Diseases of the Chest</i> ; 24: 304-309.	Descriptive paper only - no data
Scannell CH, Balmes JR. (1995). Pulmonary effects of firefighting. <i>Occupational Medicine (Philadelphia, Pa.)</i> ; 10: 789-801.	Inadequate selection process
Sjogren B, Johanson G. (2006). Mortality in Florida professional firefighters, 1972-1999. <i>American Journal of Industrial Medicine</i> ; 49: 138-140.	Letter to the Editor but no further data
Tubbs RL. (1995). Noise and hearing loss in firefighting In <i>Firefighters' Safety and Health [Review]</i> . P Orris, J Melius, RM Duffy (eds) Philadelphia.	Inadequate selection process
Turner SW, Thompson J, Rosser RM. (1995). The Kings Cross fire: psychological reactions. <i>Journal of Traumatic Stress</i> ; 8: 419-427.	Study of 50 survivors of the Kings Cross fire.

APPENDIX D: REPORT TO THE WORKERS' COMPENSATION BOARD ON CARDIOVASCULAR DISEASE AND CANCER AMONGST FIREFIGHTERS. CANADIAN INDUSTRIAL DISEASE STANDARDS PANEL (IDSP REPORT NO 13) 1994.

Since the preparation of the present report, a copy of the above report has been made available to the project team. This document was reviewed for any significant evidence which should be considered as part of the present review.

Clearly, the Canadian IDSP has its own criteria for considering a disease or illness to be work-related. Without exploring them in detail it can safely be stated that they are very different to those applied by IAC in the UK. The conclusions of the IDSP have not therefore been taken into account in preparing the present review.

The first general point to note is the age of the report and consequently of the material contained within it. Dated 1994 it clearly therefore does not include the considerable quantity of evidence published since that time, such as the sizable mortality study by Ma *et al* (2005).

Turning to the material included in the review, many of the studies included are also extracted for the present review. Notable exceptions are a number of unpublished studies, although evidence from one of these (L'Abbe and Tomlinson, 1992), substantial extracts from which are included in the IDSP report, is cited in the present review as Aronson *et al* (1994). Published papers which have not been considered in the present review include some such as that by Feuer and Rosenman (1986) which had been excluded from the present review as the Proportional Mortality Ratio data did not include confidence intervals and that by Heyer *et al*, (1990) excluded because of the considerable overlap with the study by Demers *et al* (1992).

Interpretation of the evidence presented in the IDSP report can be visually confusing because, where the source paper has included multiple comparisons, a number of these are often included in the graphical presentations.

In the reviews of different forms of cancer, data from studies reporting risk estimates for differing cancers are sometimes merged. One notable example of this is colonic cancer, which includes some material on rectal cancer which is then accorded its own review. The same data from some studies, such as that by Guidotti (1993) are thus included twice.

Finally, although the statistical significance of some estimates is acknowledged in the text, the confidence intervals around the individual risk estimates are not routinely presented.